University of Queensland

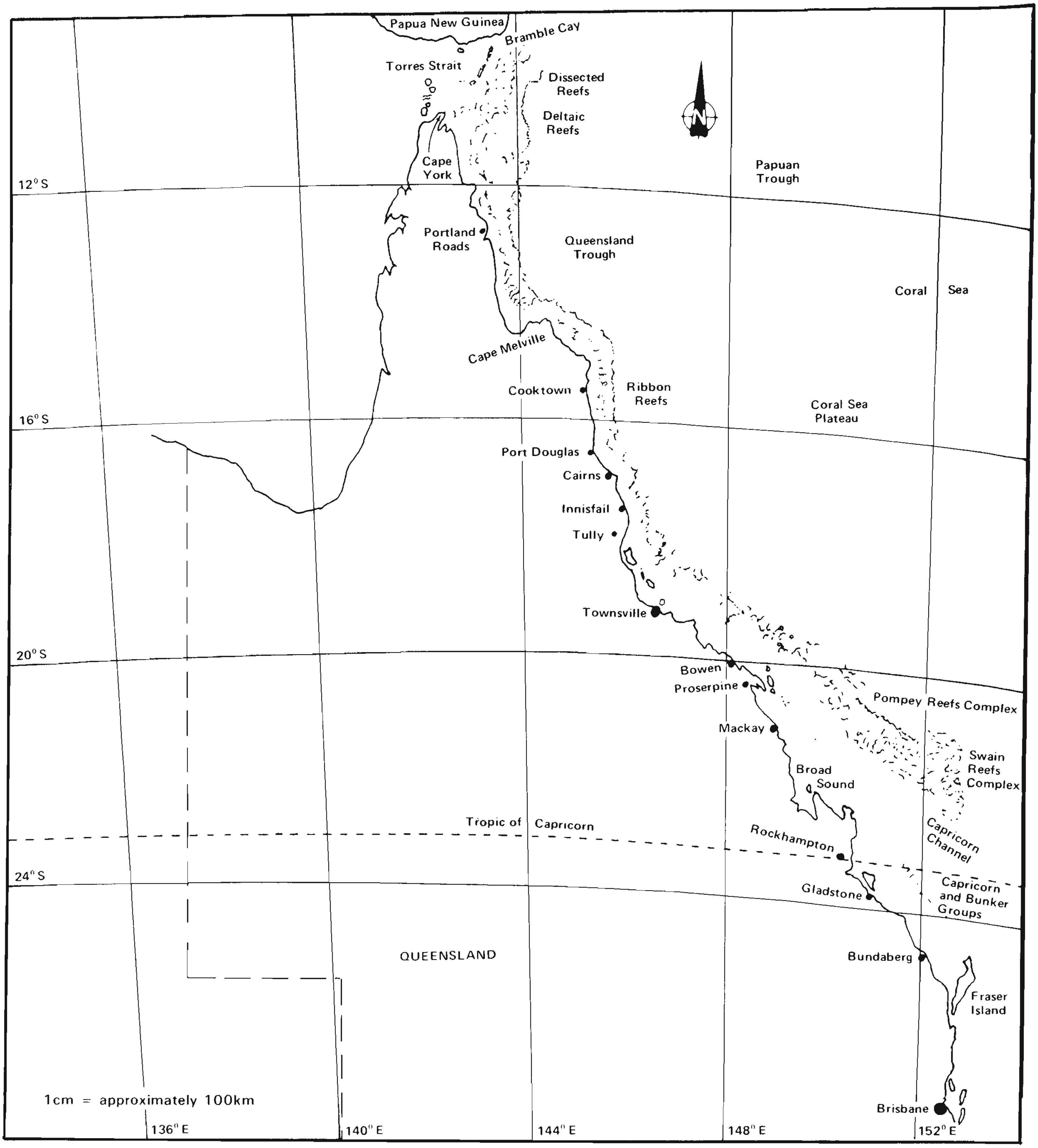
Presented to

The Fryer Memorial Library of
Australian Literature

by

University of Queensland Press

AUSTRALIA'S GREAT BARRIER REEF



Map 1 Map of Queensland showing the Great Barrier Reef region. Details of the reefs can be seen in maps 2, 3 and 4 on pages 12 and 13.

AUSTRALIA'S GREAT BARRIER REEF

Robert Endean

University of Queensland Press
St Lucia • London • New York

Typeset by Savage & Co. Pty Ltd
Printed and bound by Silex Enterprise & Printing Co., Hong Kong

Distributed in the United Kingdom, Europe, the Middle East, Africa, and the Caribbean by Prentice-Hall International, International Book Distributors Ltd, 66 Wood Lane End, Hemel Hempstead, Herts., England.

National Library of Australia
Cataloguing-in-Publication data
Endean, R. (Robert).
Australia's Great Barrier Reef.

Don '82
Fryer

Includes index.
ISBN 0 7022 1678 X.

1. Coral reef biology — Queensland — Great Barrier Reef. 2. Natural history — Queensland — Great Barrier Reef. 3. Great Barrier Reef (Qld.) — Description and travel — Guide-books. I. Title.

574.9943

Library of Congress Cataloguing in Publication Data
Endean, R.
Australia's Great Barrier Reef.

Includes index.
1. Coral reef biology — Australia — Great Barrier Reef (Qld.) 2. Great Barrier Reef (Qld.) I. Title.
QH197.E53 508.943 82-2063
ISBN 0-7022-1678-X AACR2

Designed by Horsley Dawson

Contents

Illustrations

Figures

Maps

Preface

The Great Barrier Reef is many things to many people. To some, the term conjures up visions of a tropical sea studded with coral reefs and islands and represents a place of adventure, romance and recreation. Some see the Great Barrier Reef as a place of beauty, a kaleidoscope of colour and a refuge for a host of strange but interesting animals and plants. Still others see it as the most complex ecosystem on this planet, posing a major challenge to scientists wishing to unlock the storehouse of new knowledge it contains.

To me it is all of these things and I am grateful that I had the opportunity over the last thirty years to travel along its length, to visit hundreds of its reefs and to study the fauna and flora of those reefs. Everywhere, from the atoll-like platform reefs of the Bunker and Capricorn Group and the magnificent underwater citadels of the Swain Reefs complex at its southern end to the precipitous ribbon reefs north of Cairns, and to the tide races of Torres Strait and the huge Warrior Reefs near its northern limit there is variety, colour and spectacle that are more than sufficient to make the Great Barrier Reef qualify as the Eighth Wonder of the World.

The Royal Commissions into Oil Drilling on the Great Barrier Reef and the enquiry into the crown-of-thorns starfish on the Great Barrier Reef sponsored by the Commonwealth and Queensland governments during the early 1970s revealed the apparent depth of our ignorance of many aspects of the biology of corals, starfish, and other organisms associated with coral reefs, and of the general ecology of coral reef communities. Yet, a great mass of new data on coral reefs generally and on the reefs of the Great Barrier Reef and their fauna and flora in particular had been obtained since the Second World War and had accumulated in various scientific journals. Some of it was brought together during the 1970s in the four volume work entitled *Biology and Geology of Coral Reefs* which was edited by O. A. Jones and myself and published by Academic Press. By the early 1980s the time was opportune for the production of a book incorporating new advances in our knowledge of this vast area.

Initially it was intended that the book be written for biologists and biology students. However, Mr Frank Thompson, Manager of the University of Queensland Press, persuaded me to write what was hopefully termed a definitive book on the Great Barrier Reef for a general audience. The task of writing a book suitable for both university students and a general audience was a daunting one, but it occurred to me that anybody interested in the natural sciences is a student in a sense. Moreover, there was an urgent need to provide members of the general public with sufficient information to enable them to assess logically the major threats now faced by the fauna and flora of the Great Barrier Reef as a result of past, present and projected human activities in the region. Accordingly, this book has a core of classical biology. Most of the groups of animals and plants occurring on the Great Barrier Reef, as well as many of the recent advances in our understanding of major ecological problems relating to them are dealt with in this book. In addition topics such as the importance and the future of the Great Barrier Reef, its geography and topography, its geology and mode of formation, its recent history, tourist resorts in the region, fishing, reef-walking and diving on the reefs, strange and dangerous animals that might be encountered there, and the pressing need for conservation of its fauna and flora are included. As well as providing a reliable source of information for both students of and visitors to the Great Barrier Reef it was intended that the book would be a practical memento of a visit to the Great Barrier Reef. For these reasons it was decided to illustrate this book with colour photographs showing not only the diversity of the fauna and flora of the Great Barrier Reef but also its grandeur and beauty.

Because of limitations on book size it was decided that animal groups found on the Great Barrier Reef would be dealt with principally at the family level.

A discussion of the manner in which zoologists arrange animals in taxonomic groupings will be found in chapter four and descriptions of the various family groups will be found under appropriate headings. These descriptions should be used in conjunction with relevant diagrams and colour illustrations in order to obtain an idea of the basic characteristics of each family group. Genera found on the Great Barrier Reef and belonging to each family mentioned are listed. (Plans are in hand to produce a series of books in which species belonging to each family of animals found on the Great Barrier Reef are discussed so that detailed information on the various species occurring there will ultimately become available.) The general reader of this book who is not particularly interested in descriptions of animal groups could skip through these descriptions leaving them for later reference and concentrate on the remainder of the book so as to obtain an overview of the nature of the Great Barrier Reef, of the general biology of the major groups found there, of the general ecology of coral reef communities and of the conservation problems bearing on these communities.

Most of the colour photographs appearing in this book were taken by Mr John Paterson of the Zoology Department of the University of Queensland. These photographs were augmented by inclusion of a number of pictures taken by Mr Doug Henderson of Brisbane (Illustrations no. 54, 65, 102, 103, 106, 107, 109, 111, 118, 121, 122, 157, 168, 175, 203, 204, 210, 239, 247, 268, 279, 283, 284, and 287).

Also, colour pictures were made available by Mr Russel Reichelt of A.I.M.S. Townsville (Illustrations no. 1, 5 and 6), Mr Theo Brown of Newport Beach, NSW (Illustration no. 294) and Mr John Harding of Sydney (Illustration no. 296). Colour pictures of algae (Illustrations no. 38, 39, 41, 43, 44, 45, 46, and 47) were provided by Dr A. B. Cribb of the Botany Department of the University of Queensland.

The author wishes to thank all these people for generously making photographs available for inclusion in this book. A number of pictures (Illustrations no. 12, 19, 49, 50, 56, 59, 61, 67, 68, 128, 139, 141, 142, 149, 151, 155, 178, 197, 198, 200, 201, 209, 222, 223, 240, 242, 245, 250, 251, 271, 274, 289, 290, 295, 297, 298, and 299) are from the author's collection.

It is a pleasure to acknowledge the assistance given by Dr A. B. Cribb who read the chapter dealing with algae and made several helpful suggestions for its improvement. Dr Richard Willan of the Zoology Department, University of Queensland, contributed valuable information to the chapter on molluscs and his assistance is gratefully acknowledged. Thanks are also due to Dr B. Jamieson of the Zoology Department, University of Queensland, who provided information on marine oligochaete worms; and to Miss Annabelle Monaghan and Mr W. Stablum who assisted with the preparation of diagrams and maps. Dr Ann M. Cameron, who read the book in its entirety, detected several errors, and made a number of useful suggestions for improving the presentation of subject matter.

This book is dedicated to the memory of my friends Dr Owen A. Jones, a former Chairman of the Great Barrier Reef Committee; and Mr Robert Poulson, a former Manager of Heron Island Pty Ltd. Owen Jones made a major contribution to the successful establishment of the Heron Island research station. A great deal of the new information in this book has stemmed from studies made by workers operating from this station. Bob Poulson often placed his boats at the disposal of myself and colleagues enabling us to visit numbers of reefs of the Great Barrier Reef. Some of the new information in this book was obtained during these visits. Proceeds from the sale of this book will be used to fund further research into the coral reef communities of the Great Barrier Reef.

R. Endean
1982

1

Definition, Attraction, and Importance of the Great Barrier Reef

Off the tropical north-eastern coastline of Australia is a shallow-water platform that for millennia has provided ideal conditions for coral growth. As a result, a remarkable system of coral reefs is found in this region — the Great Barrier Reef. It is the largest single collection of coral reefs known at the present time or throughout geological history.

Coral reefs may be defined as rigid shallow-water structures formed from the skeletal remains of corals, coralline algae, and other lime-secreting organisms. Usually, the remains are associated with fine detritus and compacted to form limestone. A veneer of living animals and plants that constitute the coral reef community hides the limestone core of each reef.

Although the reefs of the Great Barrier Reef collectively form a barrier to waves moving towards the eastern Queensland coast from the Coral Sea, and although they are a barrier to the unrestricted movement of shipping, they do not constitute a barrier reef as envisaged last century by the famed naturalist Charles Darwin. His now classical theory about the genesis of coral reefs was an attempt to explain the origins of coral reefs found in oceanic waters and may be summarized as follows: In the shallow water surrounding tropical oceanic islands, where conditions were favourable for coral growth, reefs grew encircling the shorelines; these Darwin termed *fringing reefs*. Owing to subsidence of the sea-floor in certain areas over the ages, some islands began to sink. As an island sank (and its area above sea-level consequently diminished), the outer edge of its fringing reef continued to grow upwards towards the sea surface, while the growth of corals near the island slowed because of the creation of unfavourable conditions. Eventually this erstwhile fringing reef was separated from the shrinking island by a body of water too deep for the growth of corals (see fig. 1). So a reef located at some distance from the island, which Darwin termed a *barrier reef*, was formed. Continued subsidence could lead ultimately to the disappearance of the island, and the former barrier reef would then appear as a ring-like structure — an atoll. In recent years Darwin's theory of the origin of oceanic atolls has been confirmed by drilling at places such as Bikini Atoll.

The geological history of the Great Barrier Reef, however, has followed a course different from that of reefs around oceanic islands. The Great Barrier Reef is a shallow-water structure which consists of numerous individual and discrete reefs, and it is only in its northern sector that chains of offshore reefs form a more or less continuous rampart extending parallel to the Queensland mainland coast. Elsewhere, the reefs occur mainly as isolated offshore structures separated one from another by bodies of water of considerable extent. Indeed, such reefs have been aptly described as "oases in the oceanic desert". The communities of animals and plants found on the coral reefs of the Great Barrier Reef are discrete assemblages, vastly different in species composition from the communities of animals and plants found in, on, and above the sea-floor separating the reefs.

A reasonably well-defined channel utilized by shipping separates the offshore reefs from the Queensland mainland and associated rocky islands. Many of these rocky islands possess narrow fringing reefs around their shorelines, and fringing reefs are also found on the mainland shore in a few places. There has been much debate whether the term *Great Barrier Reef* should include these fringing reefs as well as the larger offshore reefs. As applied to the offshore reefs, the term *barrier reef* is a misnomer, as we have seen. The term *Great Barrier Reef* can, with advantage, be applied to the whole collection of the coral reefs found on the shallow-water platform off the eastern Queensland coast between the mainland shore and the hundred-fathom (180-metre) line, and this course will be followed in this book. However, it should be appreciated that there are basic differences between the offshore reefs and the near-shore fringing reefs. These differences involve not only their structure and geological history but also the composition of their fauna and flora.

The Great Barrier Reef is important for many reasons. First it is a wilderness area — a place for natural adventure, contemplation, and recreation. Such areas become fewer each year on our crowded planet as human populations increase and urban industrialization spreads. Few terrestrial areas can rival the beauty of the reefs themselves. Seen from an aircraft, the offshore reefs appear as white-encircled emeralds set in a sapphire blue sea. The variety of form and colour exhibited by the animals and plants of the reef is more than enough to arouse the interest of even the most jaded jet-setter. Then there are the coral islands, with their dazzling white beaches fringing in many cases

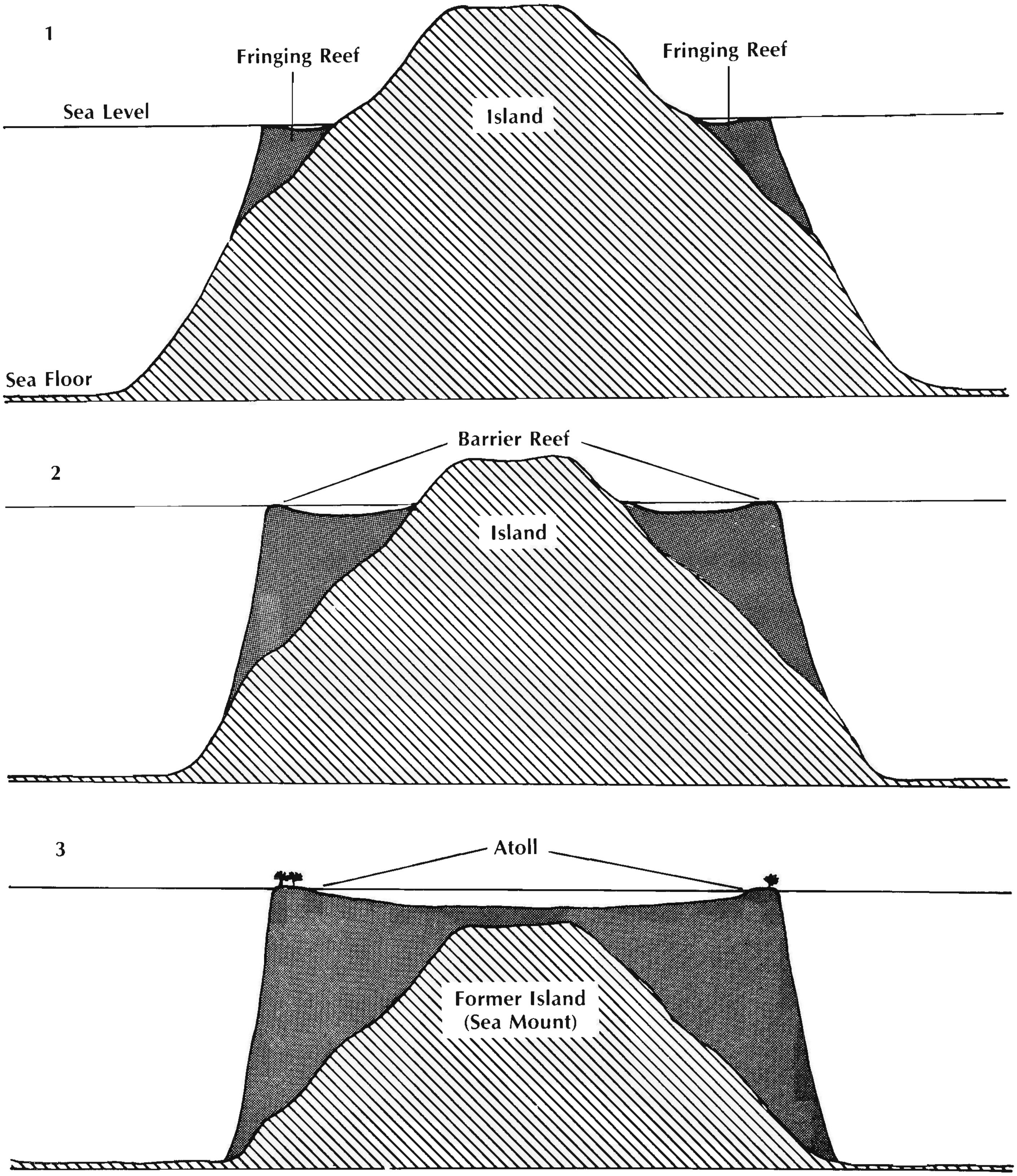


Figure 1. Diagrams illustrating Darwin's theory of atoll formation.

luxuriant vegetation. Skin and scuba diving, swimming, angling and big-game fishing, fossicking at low tide on reefs, examining and photographing the diverse fauna and flora of reefs, sailing and boating among reefs, and exploring islands associated with reefs are among the recreational activities that the Great Barrier Reef has to offer. It can be predicted that in the future there will be a marked increase in the use of underwater aquaria, illuminated underwater entertainment and conference areas, and tethered and free submersibles to enable visitors to obtain glimpses of the fauna and flora of the reefs by day and by night.

As yet, the full potential of the Great Barrier Reef as a tourist attraction and recreational centre has not been appreciated. Only a relatively small percentage of Australians, let alone overseas visitors, have seen the reefs of the Great Barrier Reef. To a large extent the relative inaccessibility of the reefs and tourist resorts of the Great Barrier Reef has been responsible for this state of affairs. The eastern Queensland coast off which the reefs are found is thousands of kilometres long; the coastal towns that provide gateways to the reefs are hundreds of kilometres apart; and the reefs and tourist resorts themselves are a long way from the coastal towns and widely scattered. Until recent years access was principally by boat, frequently involving trips of several hours duration, often in rough seas. Furthermore, as the tourist resorts located on islands are necessarily small, it was uneconomic in most cases to run daily boat services, which meant visitors were expected to stay several days at least. In some seasons, accommodation was often in short supply and booked up weeks ahead. The relative isolation of the tourist resorts has also meant that their operations have had to be self-contained, and consequently the provision of facilities such as electric power and fresh water has been expensive. Those visitors who did not wish to stay at tourist resorts have had to charter boats to see the reefs.

All this has meant that, in the past, visitors to the Great Barrier Reef have found access difficult, time-consuming, often uncomfortable, and usually expensive. Indeed, many Australians have found it cheaper and easier to visit coral reefs in such South Pacific countries as Fiji and New Caledonia. The lot of the international visitor has been worse. Prior to the 1980s the lack of an international airport to cater for visitors who wished to see the Great Barrier Reef forced them to travel to Sydney or Melbourne before changing planes and flying north again to Queensland coastal towns, there to embark on boats for the final leg of their pilgrimage to the Great Barrier Reef.

In recent years, airstrips suitable for light planes have been constructed at tourist resorts situated on the larger islands, and helicopter services have been instituted at other islands. If the tourist trade is to prosper, however, it will be necessary to operate regular and reasonably cheap aerial services, in addition to boat services, to all of the present Barrier Reef tourist resorts and to other strategically situated tourist resorts yet to be constructed. An increase in the use of helicopters (involving helicopter landing platforms on reefs) and amphibious planes is called for, as is the upgrading of airports on the eastern Queensland coast to cater for international tourist traffic to the Great Barrier Reef. Also, there is a need for radically new types of accommodation to be provided. Attention should be given to floating and submerged hotels, marinas, and specially constructed submersibles in the immediate vicinity of offshore reefs. It can be confidently predicted that when access and accommodation are improved in the ways mentioned, Barrier Reef tourism will become Australia's greatest earner of foreign exchange.

The coral reef communities of the Great Barrier Reef are among the most biologically productive of all natural communities. Their potential to provide food for humans has not been systematically investigated. Even the exploitation of obvious food sources such as fish and

Chains of offshore reefs near Lizard Island form a barrier to waves moving towards the Queensland coast from the Coral Sea.

crustaceans has been haphazard, and the harvesting of the less familiar foods (at least to Australians) provided by algae, molluscs, holothurians (*bêche-de-mer*), and the like, has been negligible. Because of the phenomenal increase in the world's population that is now occurring, it is vital that optimal use should be made of all renewable food resources. As matters stand, commercial fishing on the Great Barrier Reef is a small but important industry; many coral reef fishes, such as coral trout and the various emperors, are highly prized as food and command high prices. However, most commercial fishing for coral reef fishes is carried out by hand-lining. Better methods have not been investigated. Nor have the effects of over-fishing on some accessible reefs been investigated until recently. It is already apparent that in some areas commercial fishing on the reefs themselves will have to be carefully regulated. On the other hand, there appears to be plenty of scope for increased exploitation in the waters among the reefs of pelagic fishes such as mackerel, tuna, and bonito as well as demersal fishes such as various snappers.

The delectable crayfish found on reefs will not enter baited craypots and must be hand-collected by divers. Not a great deal is known about reef crayfish on the Great Barrier Reef, and their commercial exploitation should be put on a scientifically managed basis. Prawns and other crustaceans, and scallops, squid, and other molluscs have been exploited regularly only in a few areas in the deeper waters among the reefs and between the reefs and the Queensland mainland; again, a systematic investigation of these resources should be carried out so that the various fishing industries can be put on a secure economic basis and their full potential realized. Additional information is also needed to ensure that the exploitation of the renewable marine food resources of the Great Barrier Reef area can be so regulated that it is compatible with their conservation.

Toxic products from terrestrial plants — for example, atropine, morphine, curare, and digitalis — have long been used in medicine, and studies of the pharmacological activities and chemical structures of these products have enabled hundreds of new drugs to be synthesized. The clinical use of penicillin and other anti-microbial compounds derived from fungi has revolutionized the treatment of certain diseases. In recent years it has become apparent that a wide variety of toxic compounds, including anti-microbial agents, are elaborated by marine organisms and especially by those found on coral reefs. New therapeutic drugs are already being developed by some pharmaceutical firms from several of these toxic products, including those elaborated by Great Barrier Reef organisms. Biological activities exhibited by compounds already isolated from Great Barrier Reef organisms include activity on the central nervous system, the autonomic system, the sensory system, the neuro-muscular system, the cardio-vascular system, the respiratory system, the renal system, and the hormonal system as well as anti-inflammatory, antiviral, antibacterial, antiyeast, antifungal, antiprotozoan, antihelminthic, molluscididal, and insecticidal activity. There are cogent reasons for believing that novel compounds isolated from toxins and other bioactive compounds elaborated by Barrier Reef marine organisms will provide a major source for the new therapeutic drugs, antibiotics, and possibly the anticancer agents of tomorrow.

Portions of two platform reefs in the Capricorn Group. In the foreground is part of the tourist complex on Heron Island and a man-made boat passage and swing basin which bisects the adjacent Heron Island reef. This reef is separated by a deep channel from Wistari reef in the background.

High-grade lime for cement manufacture, constructional activities, manufacturing, treatment of ores, and agriculture is present in enormous quantities on the Great Barrier Reef. It is believed by many people that substantial amounts of this lime, particularly in the form of coral sand, could be removed in some cases without appreciable damage to coral reef communities if appropriate techniques were used. However, others doubt this and believe that the fabric of the reefs should not be interfered with in any way under any circumstances.

Oil has been found associated with fossil coral reefs in some countries, and this association has sparked interest in searching for oil in the Great Barrier Reef area. This interest was heightened by the realization that thick layers of sedimentary rocks of the type that could contain oil lay off the Queensland coast. The possibility of massive oil spills with disastrous consequences for the flora and fauna of the area has generated a wave of popular opposition to drilling for oil on the Great Barrier Reef that to date has prevented any drilling from occurring in the region. In the absence of suitable alternative fuels, however, it would seem inevitable that as the world's oil supplies run low and fuel costs increase there will be increasing agitation and political pressure for the tapping of the reservoirs of oil believed by some to be under some sections of the Great Barrier Reef and beyond in the Coral Sea. Some hard decisions will have to be made in the near future regarding the oil-prospecting leases that now cover most of the Barrier Reef area.

Many people make a hobby of collecting the beautifully coloured and often exquisitely patterned and spectacularly shaped shells of Great Barrier Reef molluscs. Also, a number of cottage industries — shell buttons, buckles, lamps, ornaments, and bric-à-brac — are based on these shells. So-called black corals (antipatharians) found in the Great Barrier Reef area provide the raw material for a form of jewellery that is rapidly increasing in popularity. Coral ornaments and utensils inlaid with turtle shell are also much in demand by tourists as mementoes of their visit to the Great Barrier Reef.

It is not generally appreciated that coral reefs possess a vast bacterial flora which together with most attached bottom-dwelling animals remove organic materials from sea water. Accordingly, coral reefs appear to act as gigantic filters helping to purify sea water and to remove pollutants. This role of coral reefs will assume ever-increasing importance in the future, as the tropical shallow-water areas off the eastern Queensland coast are particularly prone to pollution by man-made chemicals carried there by mainland streams. Moreover, the Great Barrier Reef acts as a self-repairing breakwater, giving protection to hundreds of kilometres of continental coastline and permitting the continued existence of hundreds of islands.

Because the coral reef community is the most complex of all ocean ecological systems, and because it is also the oldest ecological system in geological history, it has a powerful attraction for scientists, particularly biologists. Accordingly, biologists from diverse disciplines find much to interest them in the fauna and flora of the greatest collection of coral reefs that ever existed. Indeed, the reef communities of the Great Barrier Reef pose numerous questions. Why, for example, are there so many species of animal and plant represented

Some of the platform reefs of the Capricorn Group. The lagoon on Wistari reef with its maze of coral pinnacles is prominent in the foreground.

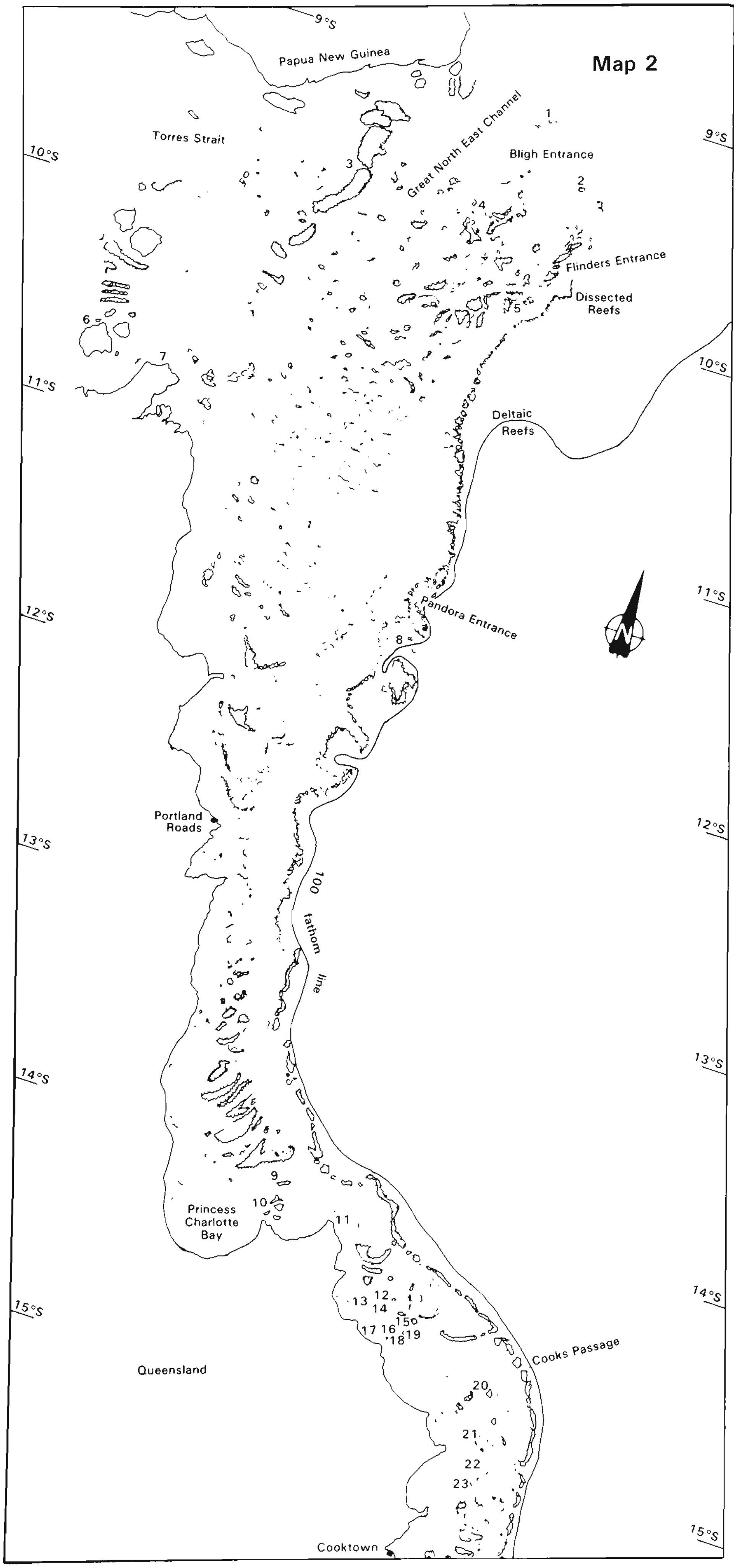
in these communities? How do they share out among themselves the limited living space available? Why are so many highly specialized but apparently rare species present? Why do so many coral reef animals produce toxic materials? Why are so many coral reef animals so brilliantly coloured? Do the populations of animals and plants present fluctuate wildly, or do they remain relatively stable? How are so many animals able to obtain sufficient food? Questions such as these tax the minds of many scientists and, of course, are also of interest to many non-scientists. Other scientists pursue goals that to some members of the public might appear more practical, such as obtaining data on animals that are to be exploited as food, or data on animal and plant products that could have a use in medicine or in industry. Indeed, the Great Barrier Reef can be regarded as a huge natural laboratory for the scientific study of marine organisms and their interactions. The few research stations that have been established on the Great Barrier Reef warrant the full support of the Australian government and people, and at least one of these stations should have international status as a centre for coral reef studies in the Indo-West Pacific region. There are few species of coral reef animal about which it could be said that adequate information on their life histories, let alone other aspects of their general biology, is available. However, the Great Barrier Reef is not the preserve of the scientist. Anybody with an enquiring mind can derive hours of pleasure from observing the animals and plants found there and can contribute to knowledge of these organisms. The educational value of the Great Barrier Reef and its fauna and flora should be far more widely appreciated than it is at present.

Much of the scientific research undertaken at the research stations on the Great Barrier Reef should be directed towards the conservation of the flora and fauna of reefs and associated islands. It should be noted that the Great Barrier Reef is unquestioningly accepted by international authorities as part of the World Heritage and is regarded by many people as the eighth wonder of the world. However, the fauna and flora of the reefs and islands of the Great Barrier Reef are under threat from human activities. The nature of the activities that affect coral reefs are outlined in chapter 24 of this book. These activities should be widely publicized so that an informed Australian public can compel their legislators to ensure that the fauna and flora of the Great Barrier Reef are conserved for future generations to wonder at, learn from, and derive pleasure from. Now is the time for action to conserve this fauna and flora.

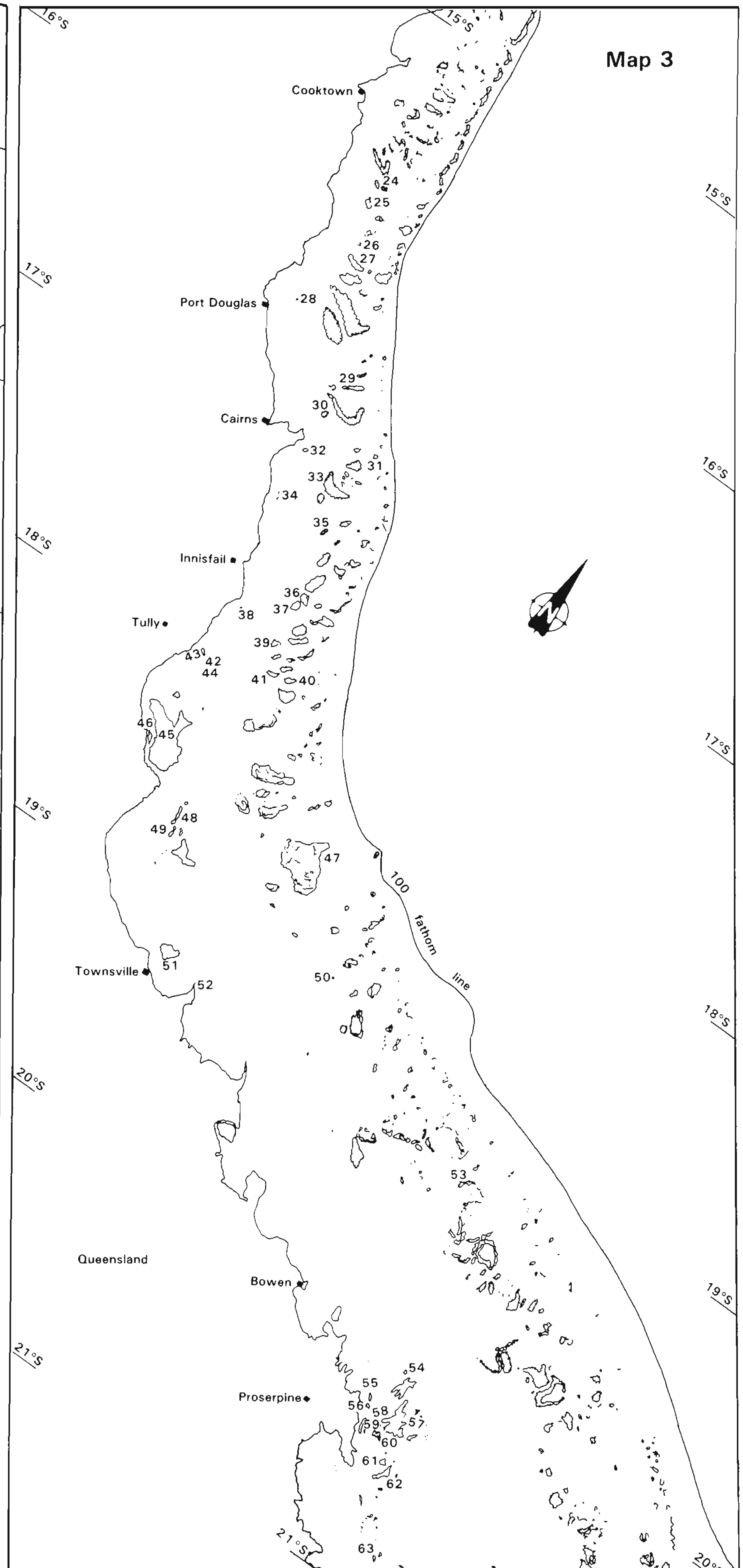
2

Geography, Topography, and Hydrographic Conditions

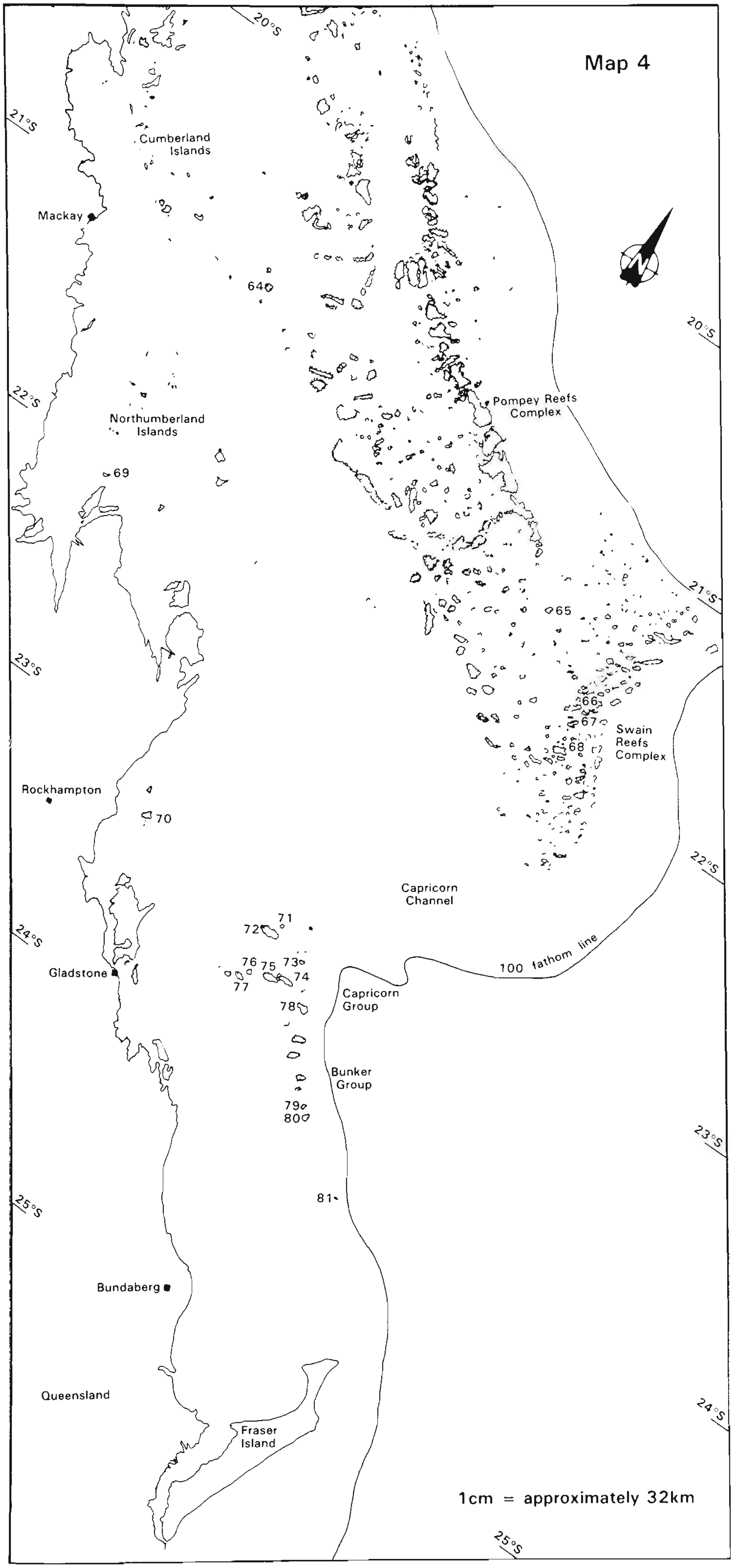
The Great Barrier Reef region embraces that section of the continental shelf of eastern Queensland which lies between the mainland coast and the hundred-fathom line to the north of Fraser Island (see map p. 00). The northern limit is usually placed at Bramble Cay, situated at approximately 9°13′ south latitude, just south of Papua New Guinea. The western boundary in Torres Strait between Papua New Guinea and Queensland may be placed conveniently at 142°30′ east longitude. Thus defined, the region occupies an area of about 250,000 square kilometres. To the north the shelf is bounded by Papua New Guinea and by the deep Papuan Trough. To the east in the northern part of this region the continental shelf drops steeply to the Queensland Trough, which is over two thousand metres in depth. In the central part the extensive (approximately 177,400 square kilometres) Coral Sea Platform, much of which is less than a thousand metres in depth, lies almost immediately to the east of the shelf. This platform also carries reefs but has a different geological history from the Great Barrier Reef region. To the south, near latitude 22°30′S, a tongue of deep water, the Capricorn Channel, intrudes into the region. The shelf is narrowest (about 36 kilometres wide) off Cape Melville (lat. 14°10′S). Both to the north and to the south of this point its eastern boundary diverges seaward from the Queensland coastline, attaining a maximum width in the north of about 350 kilometres in the Torres Strait region, and a maximum width in the south of about 412 kilometres near Broad Sound (lat. 22°S). The mean depth of the shelf increases progressively from north to south. North of latitude 16°S the shelf is generally less than 40 metres deep. Between latitudes 16°S and 20°S, depths usually range from about 40 to 70 metres. South of latitude 20°S, depths on the shelf usually range from about 60 to 130 metres.



Map 2
Papua New Guinea
Torres Strait
Great North East Channel
Bligh Entrance
Flinders Entrance
Dissected Reefs
Deltaic Reefs
Pandora Entrance
Portland Roads
100 fathom line
Princess Charlotte Bay
Cooks Passage
Queensland
Cooktown
9°S
10°S
11°S
12°S
13°S
14°S
15°S
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23



Map 3
Cooktown
Port Douglas
Cairns
Innisfail
Tully
Townsville
Queensland
Bowen
Proserpine
100 fathom line
15°S
16°S
17°S
18°S
19°S
20°S
21°S
24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63



Key to Maps

MAP 2

1. Bramble Cay
2. Anchor Cay
3. Warrior Reefs
4. Darnley Island
5. Murray Islands
6. Thursday Island
7. Cape York
8. Raine Island
9. Clack Reef
10. Flinders Group
11. Cape Melville
12. Ingram Island
13. Bewick Island
14. Watson Island
15. Howick Group
16. Newton Island
17. Sand Reef
18. Houghton Island
19. Coquet Island
20. Lizard Island
21. Eye Reef
22. Two Isles
23. Three Isles

MAP 3

24. Endeavour Reef
25. Pickersgill Reef
26. Mackay Reef
27. Undine Reef
28. Low Isles
29. Michaelmas Reef
30. Green Island
31. North-West Reef
32. Fitzroy Island
33. Sudbury Reef
34. Frankland Group
35. Flora Reef
36. Peart Reef
37. Feather Reef
38. Barnard Isles
39. Ellison Reef
40. Taylor Reef
41. Beaver Reef
42. Dunk Island
43. Bedarra Island
44. Family Group
45. Hinchinbrook Island
46. Hinchinbrook Passage
47. Slasher Reefs Complex
48. Orpheus Island
49. Palm Islands
50. Wheeler Reef
51. Magnetic Island
52. Cape Cleveland
53. Kangaroo Reef
54. Hayman Island
55. South Molle Island
56. Daydream Island
57. Whitsunday Island
58. Whitsunday Passage
59. Long Island
60. Hamilton Island
61. Linderman Island
62. Cumberland Group
63. Brampton Island

MAP 4

64. Bushy Island
65. Mystery Cay
66. Gillett Cay
67. Bylund Cay
68. Poulson Cay
69. Wild Duck Island
70. Great Keppel Island
71. Tryon Island
72. North West Island
73. Wreck Island
74. Heron Island
75. Wistari Island
76. Erkine Island
77. Masthead Island
78. One Tree Island
79. Fairfax Island
80. Lady Musgrave Island
81. Lady Elliot Island

Note Maps 2, 3 and 4. Base maps were supplied by the Surveyor-General of Queensland and reproduced by arrangement with the Queensland government.

Map 2. The northern section of Great Barrier Reef, see key.

Map 3. Central section of the Great Barrier Reef, see key.

Map 4. The southern section of Great Barrier Reef, see key.

Continental Islands

Islands and coral reefs stud the continental shelf in the Great Barrier Reef region. Near the mainland coastline numerous rocky islands occur, the largest being Hinchinbrook Island, near Tully. Many of the rocky islands are clustered at intervals to form island groups. Among the major groups are the Keppel Islands near Rockhampton, the Northumberland Islands near Mackay, the Cumberland Islands near Proserpine, the Palm Islands near Townsville, the Family group near Tully, the Barnard Islands near Innisfail, the Frankland group near Cairns, the Howick group near Cooktown, the Flinders group in Princess Charlotte Bay, and the Murray Isles near the northern tip of the Great Barrier Reef. All these rocky islands, except the Murray Isles and adjacent islands, are detached pieces of the adjacent mainland, and hence are known as continental islands. They represent the tops of partially submerged hills and mountains, and their geological structure is similar to that of the adjacent mainland.

Continental islands are at times little more than rocky outcrops protruding above the waves. Some, however, are impressive, with high mountains or steeply sloping hills. Sometimes they are bare of shrubs and trees, but often they are clothed in dense scrub and occasional patches of jungle. Some rise sheer from the water, surrounded by steep cliffs. Others are encircled by sandy beaches. Hoop pines (*Araucaria cunninghami*) are conspicuous among the trees of some of the rocky islands. The lee sides of many of the larger ones provide a haven for small craft. Passages between the large islands and the mainland, such as Whitsunday Passage and Hinchinbrook Passage, are justly famed for their scenic beauty.

Volcanic Islands

The Murray Isles formed part of a volcanic crater that was active in recent times. Likewise both Bramble Cay and Darnley Island, which lie north-east of Cape York and which are composed of andesitic lavas and ash beds, have had a volcanic origin.

Coral Reefs

The narrow coral reefs known as fringing reefs grow on the shores of many of the rocky islands and occur in places on the mainland shore itself. Elsewhere on the shelf there are reefs belonging to four different categories. Between latitudes 10°40'S and 17°S (approximately) the outermost of these reefs are situated close to the edge of the continental shelf, but north of 10°40'S and south of 17°S they are set back several kilometres from the shelf edge. From about 11°14'S to about 16°S these outer reefs form an almost continuous belt of linear reefs with recurved ends known as *ribbon reefs.* Their long axes parallel the edge of the continental shelf and they are separated one from another by narrow channels. They range from five to twenty-five kilometres in length and from three hundred to five hundred metres in width. North of this area the appearance of the outer reefs changes. Between latitudes 11°14'S and 10°S (approximately) the outer reefs occur as elongate patches which are separated by shallow meandering channels giving the appearance of

Fitzroy Island, a rocky continental island lying near Cairns.

a river delta. Hence the reefs are known as *deltaic reefs*. Their form has no doubt been influenced by the strong tidal currents found in the Torres Strait region. From about 10°S to about 9°45′S, where the outer reefs terminate, the channels between the reefs become straighter and the reefs in this region have been termed *dissected reefs*.

Between the outer reefs and the Queensland mainland, *platform reefs* occur. These are basically knoll-like formations, but the reefs present a variable surface geometry. Generally their maximum horizontal dimensions range from five to ten kilometres. Some of those lying near the Queensland mainland are only one to two kilometres in greatest dimension but bear complex assemblages of shingle ridges, exposed limestone platforms, mangrove areas, and small islands.

South of latitude 16°S, ribbon reefs are absent from the shelf, the outer edge of which gradually diverges seaward from the mainland coast. The offshore reefs in this section are all platform reefs. The innermost platform reefs of the shelf are separated by a channel from the mainland. Some of these inner platform reefs are large, up to twenty kilometres in maximum horizontal dimension, and some contain lagoons. Platform reefs become increasingly sparsely distributed as one proceeds southwards from 16°S to 19°S. However, between 19°S and 20°S they become more numerous, and from 20°S to 21°10′S, in the Pompey Reefs complex, the outer reefs are densely packed and of variable size and shape. All, however, are set well back from the hundred-fathom line. The channel separating the mainland and associated rocky islands (which usually have fringing reefs) from the innermost platform reefs of the shelf increases in width towards the south. Between latitudes 21°10′S and 22°30′S the platform reefs of the shelf are widely dispersed and form a veritable maze in the Swain Reefs complex. To the south-west this complex is separated by the Capricorn Channel from the Capricorn and Bunker Groups, which represent the southernmost reefs of the Great Barrier Reef. These lie only eighty kilometres approximately from the mainland coast.

Thus the reefs of the Great Barrier Reef span fifteen degrees of latitude and ten degrees of longitude. They are scattered over a distance of approximately two thousand kilometres. A study of recent charts indicates that there are approximately 30 dissected reefs, 30 deltaic reefs, 1,290 platform reefs, and 130 ribbon reefs on the continental shelf in the Great Barrier Reef region. Because many of the fringing reefs around continental islands and on the mainland coast are very small, their number cannot be determined with any certainty, but it is estimated there are about a thousand. While the reefs vary in size and shape, the mean area occupied by each in flat projection is estimated to be approximately ten square kilometres. Thus only about 10 per cent of the Great Barrier Reef region is occupied by reefs. The principal areas of a reef are depicted in figure 2.

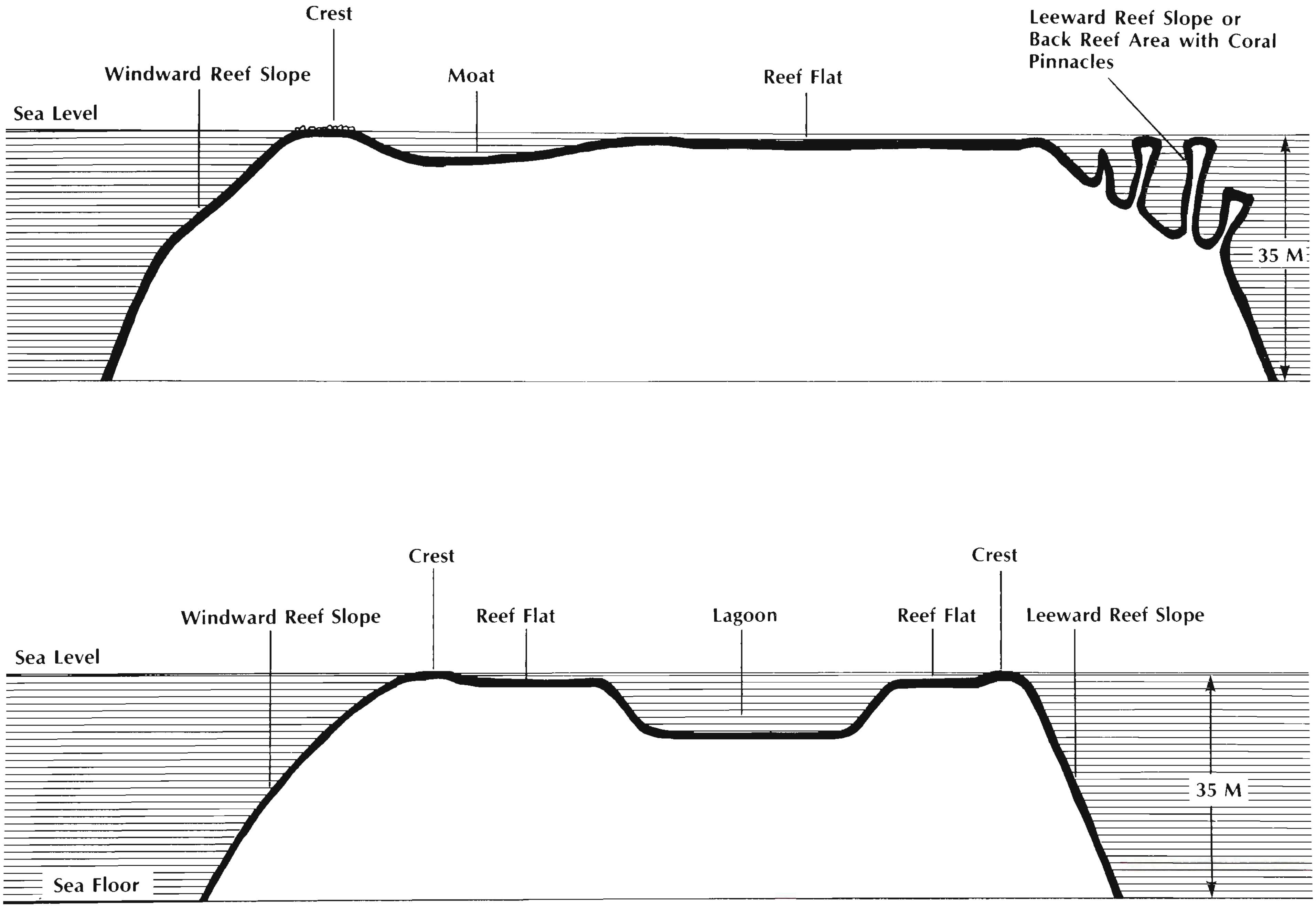


Figure 2. Vertical sections through two generalized platform reefs showing principal topographic features. Not to scale. *Top:* Platform reef with moat on outer reef flat behind crest. *Bottom:* Platform reef with lagoon.

Coral Islands

On many platform reefs there are small sandbanks, formed predominantly of pulverised foraminiferal, coral, and molluscan fragments. These materials accumulate on the lee side of the reef flats, usually in the region where waves driven around either side of the reef by the prevailing south-easterly trade winds converge. However, most of the sandbanks are unstable and alter their position, shape, and size considerably with time. They occur on platform reefs which are usually relatively large, contain a shallow lagoon, and are situated towards the outer edge of the continental shelf. If such an accumulation of sand becomes emergent above the level of the sea at high tide it forms an island known as a sand cay. It is not known precisely how this emergence comes about. Possibly cyclones associated with abnormally high tides cause a piling up of sand and debris at a level higher than usual. The island may then act as a barrier to water currents crossing the reef flat, causing the deposition of additional material around its periphery. Usually, sand cays occupy only a small proportion of the reef surface and emerge only a few metres above the level of mean low water. Many of the sand cays, such as Mystery Cay and others in the Swain Reefs area, Taylor, Beaver, Flora, and Wheeler in the central region, and Pickersgill, Undine, and Mackay in the northern region, are completely unvegetated. Others, such as Sudbury and Michaelmas in the central region, carry a few wisps of grass and sometimes a few succulents. Still others, such as Erskine Island in the Capricorn Group, carry stunted shrubs in addition to grasses and succulents. A sand cay in its climax state may carry a stand of trees or a veritable forest of trees as well as shrubs, succulents, and grasses. Most of the islands in the Bunker and Capricorn Group, Bushy Island off Mackay, and Green Island and several other sand cays in the region north of Cairns are of this kind.

Another type of coral island is the shingle cay. Some islands on platform reefs are formed basically of medium-sized fragments of corals. Pieces of branching corals, particularly *Acropora* species, are major constituents. Such shingle cays are often located on the windward side (the south-east side) of high reefs (e.g., Watson, West Hope, and Sand reefs), particularly when they are near the mainland in the northern part of the Barrier Reef where fringing reefs also occur. Typically, they occupy 5 to 10 per cent of the reef top area. Shingle islands may carry vegetation similar to that carried by sand cays. For example, cays in the southern region of the Swain Reefs complex, such as Poulson Cay, Bylund Cay, and Gillett Cay, carry coarse grasses. However, mangroves often colonize the lee side of the shingle island if it is situated near the mainland. A few cays are composed of an intimate mixture of sand and shingle, while others have regions where shingle predominates in some parts and sand in other parts.

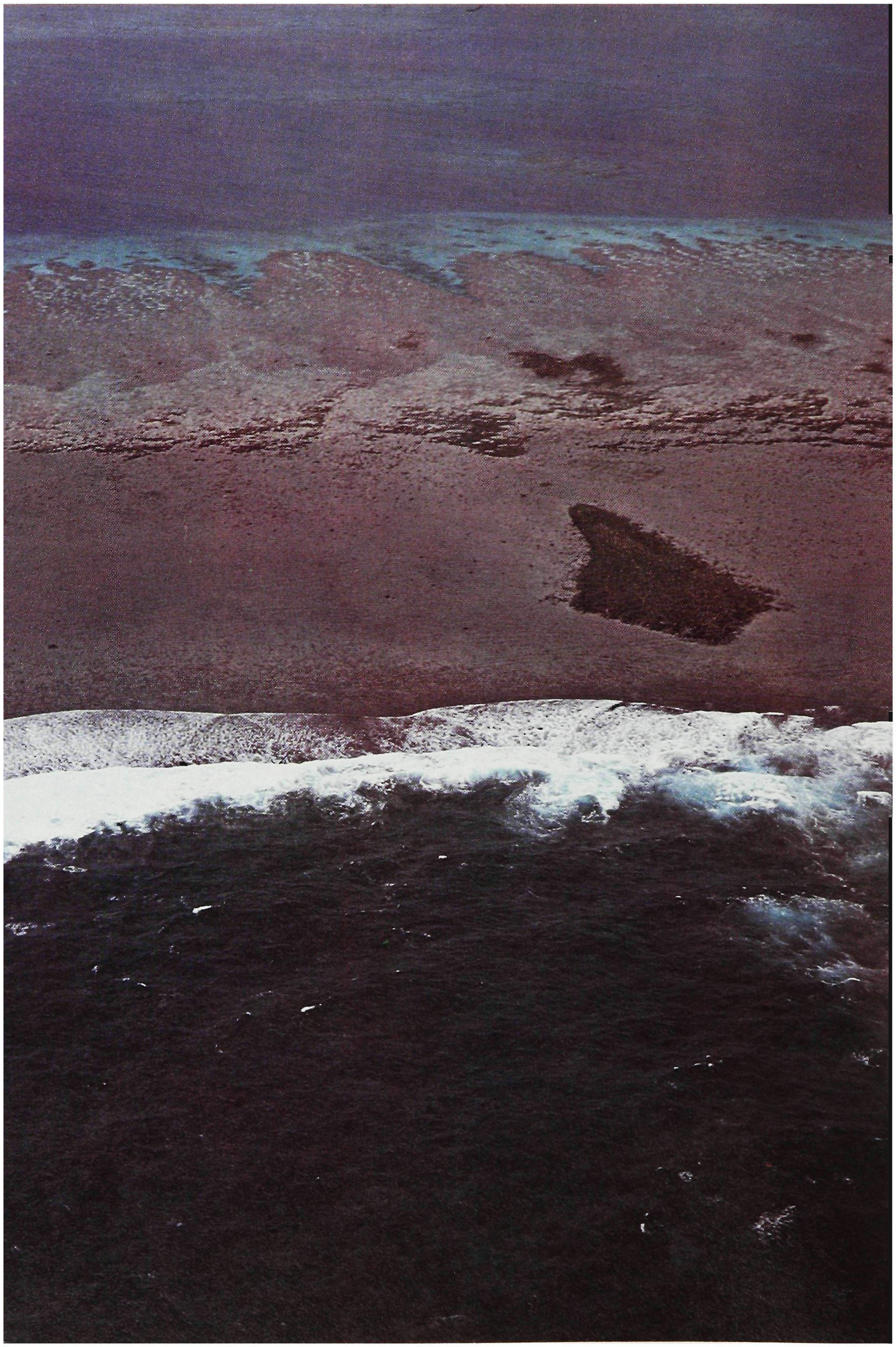
Sometimes a reef supports more than one island. The islands may be sand cays (e.g., Low Isles, Two Isles, Three Isles, Bewick, Newton, and Ingram) or composite shingle and sand cays in addition to a shingle cay (e.g., Coquet, Houghton). The sand cay at Two Isles, with an area of some 195,000 square metres, is the largest sand cay on the Great Barrier Reef.

Water Movements

Currents

Surface currents within the Great Barrier Reef region are complex, being affected by tidal movements and varying with the seasons. Two

Lizard Island, a rocky continental island with an extensive fringing reef.



Portion of a ribbon reef near Lizard Island. The bare pavement-like reef crest on which waves from the Coral Sea are breaking can be clearly seen. A reef flat shelving into the channel lying between the offshore reefs and the mainland is visible on the landward side of the reef.

major westward-flowing currents in the Coral Sea impinge on the region. These currents are the South Equatorial Current in the far north and, further to the south, the Trade Wind Drift. During the monsoon season, from January to March, these currents combine and veer south, forming the East Australian Current. At such times water from the Arafura Sea flows through Torres Strait and also contributes to the general southerly set of the currents along the outer edge of the Great Barrier Reef region. During the remainder of the year the southerly set persists in the region south of approximately latitude 18°S, but in the region north of about that latitude the currents flow north-west along the outer edge of the Great Barrier Reef region towards Torres Strait. On the continental shelf within the region, surface currents have been little studied. When south-easterly trade winds blow, surface currents in the Townsville-Cooktown region flow north-west parallel with the coastline. During November-December, when winds blow frequently from the north, surface currents flow to the south-east in the region between Townsville and the Whitsunday Isles.

Tides

Tidal waves move westward towards the Queensland coast where they impinge on the Great Barrier Reef region. The tides are mixed semi-diurnal; that is, a high and a low tide occur within every twelve-hour period approximately. During the flood tide a build-up of water occurs in the region on the shallow continental shelf, particularly at its southern and northern ends. In the vicinity of Broad Sound (lat. 22°S), where the shelf is widest, there is a tidal rise and fall of approximately 11 metres during periods of spring tides. Further south in the Capricorn and Bunker groups the tidal range at springs is about 3 metres, and in the vicinity of the Northumberland and Cumberland Islands off the central Queensland coast it is about 4 to 6 metres. In the narrow waterways between the coast and the Cumberland Islands, maelstrom effects caused by tidal currents have been identified in satellite pictures of the area. Further north, in the Cairns region, the tidal range at springs is only 1.7 metres. This range increases again to the north, attaining a maximum of about 4 metres in the Torres Strait region. The biggest spring tides occur in December–February at night and in May–August during the day. At extreme low water there may be considerable exposure of reef flats.

Tidal currents in channels around and between reefs can attain considerable velocities, particularly in regions where the tidal range is great and gaps between reefs are narrow, as in the Pompey Complex east of Mackay or in the deltaic reef area near the extreme northern end of the Great Barrier Reef.

Winds

South-east trade winds blow almost constantly from March to November in the Great Barrier Reef region. Mean wind velocities range from 18 to 29 kilometres per hour (10 to 15 knots). During the summer months (December–February) the dominant winds are north-westerlies in northern parts of the region. These are linked to the arrival in December of the north-west monsoon off Cape York. Usually the monsoon front extends southwards during January and early February, often as far as the Cairns-Innisfail districts, before retreating northwards. Over the remainder of the Great Barrier Reef region, winds may be variable during the summer months. In some years periods of calm weather, each period extending over several days, have been recorded during summer months.

Erskine Island, a coral cay surmounting a platform reef in the Capricorn Group.

Cyclones

Tropical storms known as cyclones, with centres of low pressure ranging down to 950 millibars, are spawned most years in the Coral Sea or further east in a belt lying between latitudes 8°S and 18°S. They can occur from December to April, but usually occur in January, February, or March. Two or three appear each year, on average, but only about half those generated move into the Great Barrier Reef region. The remainder move southwards parallel with the Queensland coast or in a general south-easterly direction. Initially, their course is frequently erratic. Violent winds, gusting to velocities in excess of 200 kilometres per hour, occur near the centre of the cyclone.

Often the cyclones move in a westerly or south-westerly direction and eventually cross the Queensland coast. Huge seas are often generated by the cyclonic winds, and these also cause a piling up of water in shallow-water areas, giving the impression of abnormally high tides. Naturally, cyclones wreak havoc with small ships, and prudent sailors run for shelter when the "glass begins to fall" during the cyclone season. Extensive damage is caused to corals on coral reefs in the path of a cyclone, particularly if the cyclone strikes what is normally the lee side of a reef.

Water Temperature

Except between latitudes 14°S and 15°S, water temperatures in the Great Barrier Reef region vary rather uniformly with latitude. Mean temperatures range from about 27.5° at the northern end to about 24°C at the southern end. Highest sea temperatures occur in January in the northern region (approximately 30°C) and in February in the southern region (approximately 28°C). Lowest sea temperatures occur in June–July in the northern region (approximately 24°C) and in July–August in the southern region (approximately 20°C).

Between latitudes 14°S and 15°S, periods occur, particularly in February and May, when sea temperatures are lower than those to the north and south. This section of the Great Barrier Reef region is the narrowest section, and water temperatures there are probably affected more by mixing with Coral Sea water than are water temperatures in other sections.

Rainfall, Freshwater Run-off, and Salinity

The south-east trades are dry, and rainfall in the Great Barrier Reef region is concentrated over the summer months. It is heaviest in the Cairns region, where annual totals are around 2,000 millimetres, and decreases both to the north and south of this region. Outflow from coastal rivers during the summer monsoon season can be considerable. For example, the outflow from the Johnstone River at Innisfail during the three-month period December 1978 to February 1979 was approximately 3.43 million megalitres. At such times sediment is carried considerable distances out to sea, and waters bathing the reefs of the Great Barrier Reef in the region can be quite turbid.

3

History of the Great Barrier Reef

Coral reefs have had a long evolutionary history. Calcareous structures formed by living organisms and which could be termed reefs began to appear in the earth's tropical seas at least two billion (2,000 million) years ago. However, the calcareous deposits formed, called stromatolites, were the work of plants known as blue-green algae. It was not until the Cambrian period, some 600 million years ago, that animals became associated with the algae. These primitive animals resembled sponges and were called archaeocyathids. After 60 million years they became extinct. Then, some 480 million years ago, two other groups of animals, the bryozoans and the first corals (the *tabulate corals*) became associated with algae on reefs in a major way. Stromatolites persisted on these reefs, but other calcareous algae, called *coralline algae*, began to flourish there about the same time as the tabulate corals. The latter were later joined by another group of primitive corals called *rugose corals*. These coral reef communities persisted for about 100 million years, then they suffered a catastrophic collapse. During the next 100 million years, tabulate and rugose corals played a minor role as reef builders and, indeed, they became extinct about 215 million years ago.

About 200 million years ago the first representatives of the modern group of corals, the *scleractinian corals*, appeared and became associated with coralline algae on reefs. They flourished for the next 130 million years, and at one stage the group contained more genera than it does today. Other animals became associated with them on reefs; sometimes, as was the case with a group of molluscs called *rudists*, they played a greater part in reef formation than the corals. Then about 70 million years ago coral reefs disappeared abruptly from the fossil record for a period of about 20 million years. Subsequently coral reefs gradually reappeared and coral reef communities similar to those existing today were formed. The dominant feature of these communities was the association between scleractinian corals and coralline algae, a feature that has persisted to the present day.

Of course, the history of coral reefs just outlined did not run its course in the Great Barrier Reef area. That area did not exist as a geographical entity until a few million years ago. Indeed, Australia itself has not always had its present geographical position relative to other continents and to the poles. Near the beginning of the Triassic period about 225 million years ago, the present continents were fused into a single super-continent named Pangaea, which had a peripheral shallow-water margin on which reefs grew. Marine climates were mild and water temperatures were much warmer, even at higher latitudes, then they are today. Subsequently Pangaea broke up, splitting initially into a northern super-continent called Laurasia and a southern super-continent called Gondwana. In turn, these super-continents gradually fragmented, and the fragments became the continents of today. Slowly their positions relative to one another changed, the land masses being propelled by forces generated deep within the earth's crust. This is the phenomenon of continental drift.

By late Cretaceous times, some 65 million years ago, Gondwana had fragmented into South America, Africa, India, and Australia-Antarctica. Australia-Antarctica was then situated near the South Pole. Subsequently Australia-Antarctica split apart and Australia drifted north towards the Equator. By Miocene times, some 28 million years ago, the north-eastern coast of Australia had moved into the tropics and was favourably placed for the development of coral reefs. Apparently, as a result of faulting or down-warping of the continental margin, a shallow marine basin had been formed off the north-eastern coast. Corals flourished in this basin, which underwent slow subsidence during most of the Miocene period, which lasted for about 16 million years. As a result, the north-eastern coast became a drowned coast with coastal mountains plunging into the sea and isolated peaks protruding from the sea as rocky islands. Also, the coral reef communities grew upwards towards the sea surface from the sinking ocean floor. Sediment was trapped in the framework formed by corals and coralline algae, and the calcareous material became consolidated, then lithified as reef limestone. This material provided the foundation for attachment of later organisms, and so reefs were gradually built up, their sizes and positions being governed by the topography of the marine basin and by hydrographic conditions operating there. Probably the subsidence and reef building continued through the Miocene and the succeeding Pliocene period, up to the beginning of the Pleistocene period about a million years ago. By that time the major zones of the Great Barrier Reef and the positions of the reefs there must have been much as they are today. However, at the extreme northern end of the Great Barrier Reef region, volcanic activity occurred during the Pleistocene period and affected the development of reefs in that area.

There then occurred the remarkable Pleistocene lowerings of sea level stemming from the locking up of water in massive ice-caps, particularly in polar regions. It has been estimated that, overall, mean sea level was lowered by fifty to sixty-five metres. This would have resulted in the draining of much of the shallow water areas lying off the Queensland coast and their exposure to sub-aerial erosion for extended periods. At such times the former platform reefs of the Great Barrier Reef must have stood up from a gently sloping plain as flat-topped limestone mesas and the erstwhile ribbon reefs in the northern part of the Great Barrier Reef region must have resembled enormous dykes running along the edge of a shrinking sea. It seems likely that early Australian Aborigines lived on the coastal shelf and gazed on these massive limestone ramparts before the sea finally returned to the shelf some ten thousand years ago, when the ice-caps melted. As the water rose, it gradually covered the eroded cores of the earlier reefs. Corals and other members of the coral reef community once again settled on these limestone cores. Again the reefs grew vertically towards the surface, although their rate of growth failed to keep pace with the rate of increase in water depth. Finally the sea stopped rising and even fell slightly about three thousand years ago, and this established an upper limit to vertical growth of the reefs. The reefs reached this upper limit at various times during the last three thousand years. Only some peripheral growth was then possible, depending on local conditions. Coral islands formed on some reefs as a result of the accumulation of debris. Also, exposed rubble accumulating on some reefs near the coast acted as a trap for silt carried from the mainland and this in turn led to the establishment of mangrove forests. So the stage was set for the arrival of Europeans, the beginning of the recorded history of the Great Barrier Reef and the unravelling of its prehistory.

Australian Aborigines probably lived for several thousand years on parts of the coastal shelf where the reefs of the Great Barrier Reef now stand before the region was gradually flooded by the rising sea between about ten thousand and six thousand years ago. As the waters rose, the Aborigines would have gradually withdrawn to higher coastal land. Subsequently, after sea-level stabilized near its present height, they probably made frequent visits to many of the newly formed fringing reefs and some of the more accessible platform reefs in search of fish, turtles, molluscs, and crustaceans. Recent archaeological evidence indicates that some of the Queensland continental islands have long been used by Aboriginal groups who foraged on near-by reefs. Much of the food gathered on the reefs was eaten around the camp fires, but some of the shells collected, such as baler shells (species of *Melo*) were traded with inland tribes. Art created by the Aborigines centuries ago still adorns the walls of caves and rock overhangs on some of the islands.

A few hundred years ago, navigators from other lands began visiting the Great Barrier Reef region. Although the Englishman James Cook is usually credited with the discovery of the Great Barrier Reef in 1770 during his epic voyage along the eastern Australian coast, it is likely that other navigators preceded him. The Frenchman Bougainville saw reefs of the Great Barrier Reef from the Coral Sea side in 1768. Indonesians, Malays, Chinese, Moors, and even ancient Egyptians have been thought by some to have ventured into the region centuries before Cook. However, supporting evidence is virtually non-existent. On the other hand, there is supporting evidence for the view that the Portuguese discovered the Great Barrier Reef and charted much of Queensland's eastern coastline in the early sixteenth century. This evidence takes the form of maps produced at Dieppe, France, in about 1540. The maps were based on earlier maps smuggled out of Portugal. (The Portuguese of the early sixteenth century pursued a policy of keeping secret discoveries made by their mariners.) When adjustments are made for magnetic deviation and type of projection originally used to maps produced at Dieppe of a large land mass shown lying to the south of Java, Australia's northern and eastern coastlines become apparent, the Queensland coast, in particular, being depicted with remarkable accuracy.

As a result of his researches, K. G. McIntyre has suggested that the Portuguese navigator Cristovao de Mendonca sailed through Torres Strait from west to east in 1521 before turning to the south and charting the eastern Australian coast as far to the south as eastern Victoria. Be that as it may, one of the Dieppe maps (that prepared by the cartographer Desliens) shows what appears to be reefs beginning near a point where Cooktown now stands. The near-by coast was appropriately named "coste dangereuse" on the map, and it is in this region that the platform reefs of the Great Barrier Reef come closest to the mainland. Ironically, one of the reefs prominently marked on the map could well be Endeavour Reef, which Cook's vessel struck and on which it was almost wrecked in 1770, more than two centuries after Desliens produced his map of the region.

After the *Endeavour* was lightened by jettisoning ballast and equipment, such as six of the guns (recovered in 1969), the ship was hauled from the platform reef that almost claimed her and taken for repair to the mainland river that now bears her name. When their ship was repaired and revictualled, Cook and his crew continued their voyage northwards. They immediately found their passage impeded by the numerous islands, fringing reefs, and platform reefs that lie near the mainland between latitudes 15°30′S and 14°30′S. From the highest point on one of the islands, which he named Lizard Island, Cook obtained his first glimpse of the ribbon reefs of the Great Barrier Reef. He wrote: "When I looked around I discovered a reef of rocks, lying between two and three leagues without the islands and extending in a line N.W. and S.E. farther than I could see, upon which the sea broke in a fearful surf; this however made me think that there were no shoals beyond them and I conceived hopes of getting without these, as I perceived several breaks or openings in the reef." Cook took the *Endeavour* through one of these openings to the deep water of the Coral Sea. However, further to the north, near latitude 12°30′S, he was forced by a combination of events to re-enter the reef and island-strewn channel between the ribbon reefs and the mainland coast and to sail within this channel until Cape York was reached. There he turned west through Torres Strait.

Another remarkable mariner, William Bligh, was soon to follow Cook through Torres Strait. After the mutiny on the *Bounty*, Bligh and loyal members of the crew were cast adrift in an open boat near Tahiti. By an astonishing piece of seamanship, Bligh took his puny craft across the Coral Sea to a point near the northern tip of the Great Barrier Reef where he found a passage that permitted him to enter Torres Strait.

Yet another famous navigator was soon to pit his skills against the hazards posed by the Great Barrier Reef. During a voyage in 1802, Matthew Flinders charted the more southerly of the Cumberland Isles and then sailed northwards to a point near latitude 20°S before turning to the east and passing through a passage in the Great Barrier Reef that now bears his name.

Initially, trading ships plying between the new colony of New South Wales and Europe sailed in the Coral Sea to the east of the Great Barrier Reef on their northerly run before turning west and passing through one of the many passages in the Great Barrier Reef in the vicinity of Torres Strait. By the 1840s, however, some ships had begun to use the channel that lay between the offshore reefs of the Great Barrier Reef and the mainland. Although shorter, it was more hazardous than the Coral Sea route. Pilots with detailed knowledge of the channel were soon employed. This embryonic pilot service was ultimately to become the famous band of master mariners known as the Torres Strait Pilots. The hazard that the Great Barrier Reef posed to navigation in the days of sail is attested to by the hundreds of wrecks that lie in the region. One of the most famous is that of the *Pandora*, which was returning to England with some of the hapless mutineers from the *Bounty* in 1797. The *Pandora* was wrecked at the entrance to a passage at latitude 11°22°S which now bears her name. The wreck was located in November 1977.

Low Isles, a coral cay near Port Douglas. Buildings associated with the lighthouse establishment were used by scientific expeditions in 1928–29 and in 1954.

In order to make navigation safer in the channel between the reefs and the mainland, comprehensive surveys of the channel were undertaken. Initially these involved ships of the British navy. The first systematic survey of the Great Barrier Reef region extending from its southern to its northern tip was made by HMS *Fly* and HMS *Bramble*, under the command of Captain Blackwood, in the period 1842–46. Subsequent surveys attempted to fill in some of the many gaps in knowledge of the region. This century, survey and hydrographic vessels of the Royal Australian Navy have taken up the task. Despite all this survey activity, the sea-floor contours in the immediate vicinity of platform reefs that do not abut on the channel used by shipping are still usually poorly charted, as are the reefs themselves in some areas such as the Swain Reefs complex. Indeed, even some of the cays in this complex were still being "discovered" and placed on official charts in the 1960s.

Some of the reefs and many of the continental islands of the Great

Barrier Reef were named by Cook in 1770. Others were named by officers on various survey vessels. Not surprisingly, many of the reefs were often named after ships and naval officers. Some, however, were named after animals and two after gin distillers! Many reefs are still without official names.

During the nineteenth century, settlement gradually moved north along the Queensland coast, and the resources of the Great Barrier Reef began to be utilized. By the 1870s *bêche-de-mer* was being collected for export at places such as Green Island, near Cairns. Pearl-shell was at that stage being fished intensively in the Torres Strait region. Trochus-shell and green snail were subsequently taken in quantity from the reefs. In 1893 the commissioner of fisheries to the government of Queensland, William Saville-Kent, in a fascinating book dealing with the Great Barrier Reef, wrote: "Large quantities of bleached coral are utilized, in conjunction with Barrier Reef shells, as the orthodox adornment of innumerable oyster saloons throughout the Australian colonies, while many of the more ornamental varieties find a ready sale among retail purchasers for household decoration." Apparently the Great Barrier Reef fishing industries were slower to establish themselves. Saville-Kent noted in 1893, "The fishing industries of Queensland, as far as they relate to the fresh fish supplies of the larger centres of population, are particularly in their infancy." Towards the close of the nineteenth century some of the rich guano deposits on islands of the Great Barrier Reef were worked by phosphate companies. However, the deposits were soon worked out. Turtle meat and turtle soup canning activities began at the southern end of the Great Barrier Reef in the early years of this century. Decimation of turtle stocks in the area put an end to the turtle canning industry but gave birth to another industry in the area — tourism. The turtle cannery at Heron Island was converted into a tourist resort in 1932. It is tourism that appears likely to be the major industry on the Great Barrier Reef in the forseeable future.

As far as scientific exploration of the Great Barrier Reef is concerned, naturalists on board the *Endeavour* were the first to collect and record some of the plants and animals of the region. Joseph Beete Jukes, naturalist on board HMS *Fly*, visited many of the reefs in 1842–43 and produced an account of his visit in 1847. He was followed by three famous scientists: T. H. Huxley, on HMS *Rattlesnake* in 1848–49; Charles Darwin, on board the *Beagle* in 1859; and the American Alexander Agassiz, who visited the region in 1896. Unfortunately, circumstances prevented them from carrying out major studies in the region. In his celebrated work dealing with the Great Barrier Reef, Saville-Kent provided in 1893 superb photographs of corals and other reef organisms. He also initiated some experiments relating to the growth of massive corals that were completed early this century by the American worker A. G. Mayer. H. L. Clark, another American worker, visited the Murray Islands at the northern end of the Great Barrier Reef in 1921 and laid the foundation of much of our knowledge of the echinoderm fauna of the Great Barrier Reef. During the first half of this century many Australian workers, particularly workers from the Australian Museum such as Charles Hedley, Tom Iredale, Frank McNeill, and Gilbert Whitley, contributed significantly to our knowledge of the marine fauna of the region and Australian scientists have subsequently figured prominently in Great Barrier Reef research.

In 1922 a scientific society, the Great Barrier Reef Committee, was founded to expedite the scientific investigation of the Great Barrier Reef. In attempts to determine whether subsidence was involved in the formation of this extensive structure, the committee organized the sinking of two bores. One was sunk to a depth of approximately 183 metres at Michaelmas Cay, near Cairns, in 1926, the other to a depth of approximately 223 metres at Heron Island, near the southern end of the Great Barrier Reef, in 1937. Neither bore reached the basement rocks underlying the reefal sediments, but information derived from the cores obtained has been supplemented by more recent data derived from deeper exploratory bores sunk by oil companies at the northern and southern ends of the Great Barrier Reef. All this information has enabled geologists to provide an account of the geological history of the Great Barrier Reef.

The Great Barrier Reef Committee was also deeply involved with the planning and organization of two expeditions to Low Isles. There was a major expedition in 1928–29, involving mostly British scientists, which laid the foundations of much of our knowledge of the general biology and taxonomy of Great Barrier Reef organisms, and a short expedition in 1954 which examined changes that had occurred at Low Isles in the intervening twenty-five years. In 1951 the committee began the construction of the Heron Island Research Station. Construction of this station was a pioneering venture by a scientific society which is without parallel in the relatively brief history of Australian science. It has enabled hundreds of scientists both from Australia and from other countries to live and work right on a reef of the Great Barrier Reef. As a result, there has been a marked increase in our knowledge of the biology of organisms found at the southern end of the Great Barrier Reef. The Heron Island Research Station was recently given to the University of Queensland by the Great Barrier Reef Committee.

In recent years other research stations have been opened on the Great Barrier Reef. These include the small One Tree Island Research Station (adjacent to Heron Island), operated by the University of Sydney; the Lizard Island Research Station, operated by the Australian Museum; and the Orpheus Island Research Station, operated by James Cook University. In addition, many scientists at the Australian Institute of Marine Science at Cape Cleveland, near Townsville, are involved with studies of problems relating to the adjacent area of the Great Barrier Reef. An increase in scientific knowledge of this central region and its fauna and flora can now be expected. In order to facilitate the obtaining of scientific information from the northern region of the Great Barrier Reef, a field station is now required somewhere near the northern tip of this region, possibly in the Murray Isles area.

4

Classification and Naming of Animals and Plants

Before discussing the living animals and plants that constitute the coral reef communities found on the Great Barrier Reef, it will be necessary to consider briefly the system of naming and classifying animals and plants used by zoologists and botanists.

The animal kingdom includes such diverse members as corals, birds, crabs, and starfish. Moreover, there is a bewildering array of different kinds of coral, bird, crab, and starfish. Zoologists seek order amidst this apparent chaos. By comparing the structural features of animals it is possible to split the animal kingdom into groups, the members of each group having many features in common. Thus corals, birds, crabs, and starfish are obviously different structurally and can be placed in separate groups. Each group can be subdivided further, still on the basis of differences in structural features (the process is known as classification) until a group of animals is obtained whose members resemble each other so closely that no structural basis can be found for subdividing them further. This final grouping is the species. The species is a fundamental unit in biology, just as atoms and sub-atomic particles are fundamental units in physics and chemistry. It is a criterion of a species that the members of such a grouping can interbreed and that they do not normally interbreed with other species, or if they do, the resultant offspring are incapable of breeding.

In the eighteenth century the famed Swedish naturalist Linnaeus proposed a system of classification which, in its essentials, is accepted today. His first major division or splitting of the animal kingdom gave rise to groups called phyla (sing. phylum). There are over twenty phyla recognized today, but many of them contain relatively few species. A phylum may be subdivided progressively into subphyla, classes, subclasses, orders, suborders, families, subfamilies, genera (sing. genus), and finally species. Not all these subdivisions are usually employed in each case, but the majority are.

The coral known on the Great Barrier Reef as the branching ivory coral will be used to illustrate how this system of classification operates. The basic body plan of corals is a sac-like body with a central stomach cavity possessing an opening, the mouth, at one end. The mouth is surrounded by tentacles that bear microscopic structures called *cnidae* or *nematocysts*, which are used in prey capture. The body wall consists of three layers, the middle layer having a jelly-like appearance. All animals that possess cnidae and a basic body plan

The branching ivory coral, *Acrhelia horrescens*, a member of the family Oculinidae.

similar to that just described are placed in the phylum Cnidaria. Thus corals, jellyfish, hydroids, anemones, soft corals, sea-pens, sea-fans, and their kin are placed in this phylum. Members of the phylum that have a jellyfish (medusa) stage in their life cycle, such as jellyfish and hydroids, are placed in the subphylum Medusozoa, and those members which lack such a stage are placed in the subphylum Anthozoa. Corals do not have a medusa stage in their life cycle and hence are placed in the subphylum Anthozoa. Members of this subphylum may be placed in one of three classes depending on the arrangement of their tentacles and the way their stomach cavity, termed the *coelenteron*, is divided. If members have six (or multiples of six) unbranched tentacles and the coelenteron is divided by a number of paired partitions, they are placed in the class Zoantharia. Corals have these structural features and so are placed in this class, along with anemones, zoanthids, and their kin. Representatives of this class are then placed in one of four orders depending upon their possession of a collection of structural features that characterize a particular order. Since the outermost layer of their body wall secretes a hard limy skeleton, corals are placed in the order Scleractinia. Members of this order are then placed in one of five suborders depending on the nature of their tentacles and the arrangement of vertical radiating partitions known as *septa* in their skeletons. Study of the branching ivory coral found on the Great Barrier Reef would lead to its being placed in the suborder Faviina, individuals belonging to which possess more than two rings of tentacles around the mouth and have septa that are toothed. Features of the coral skeleton as outlined in chapter 5 are then used to subdivide the suborder into families. The branching ivory coral under consideration has the features possessed by members of the family Oculinidae. It could be placed in one of the two genera (*Galaxea* and *Acrhelia*) of this family that have been recorded from the Great Barrier Reef on the basis of whether it forms a hemispherical or lobed colony or whether it branches. Since it is a branching form, it belongs to the genus *Acrhelia*. Only one species, the species *horrescens*, belonging to this genus is known. Accordingly, the complete classification of the branching ivory coral is as follows:

Phylum	Cnidaria
Subphylum	Anthozoa
Class	Zoantharia
Order	Scleractinia
Suborder	Faviina
Family	Oculinidae
Genus	*Acrhelia*
Species	*horrescens*

When referring to any animal, it is not necessary to give each of these groupings. The last two groupings, the genus and species, suffice. Thus in zoological parlance the branching ivory coral becomes *Acrhelia horrescens*. The second part of the name is written with a small initial letter and both genus and species are italicized. Every species of animal known to science is given such a two-part scientific name, which is usually derived from Latin or Greek.

In the zoological literature there are written descriptions and figures of the known animal species, and it is possible for any zoologist with access to this literature to ascertain the scientific name for any species collected provided the species is known to science. Most museums, too, contain specimens of local animals complete with their correct scientific names, and it is possible to have animals identified (i.e., given their scientific names) by the museum authorities. It will be appreciated that common names conferred on animals may vary from district to district and from language to language. Hence it is essential that an agreed internationally recognized scientific name be conferred on each species of animal.

Botanists use the same system of classification and naming employed by zoologists. However, in place of phyla and subphyla they refer to divisions and subdivisions.

Some of the groups of animals found on the Great Barrier Reef have been little studied, and many contain undescribed species. At the present state of knowledge it is not possible to identify every species or even genus encountered on the Great Barrier Reef. However, for most groups it is usually possible to place the animal in its correct family. Consequently, the animals mentioned in this book are mostly dealt with at the family level. Another reason for adopting this approach is to keep the length of the book within reasonable limits. A common name, as well as the scientific name, is given for each family listed. After a study of relevant descriptions, diagrams, and photographs provided in the book, it should be possible for the reader to put the majority of animals encountered in their correct families. Some of the common genera belonging to each family listed are given to assist the reader in identifying specimens encountered on the Great Barrier Reef. A few groups of animals are so poorly known that they are dealt with at levels of classification above the family level.

5

The Reef Builders — Hard Corals

Animals known commonly as hard or stony corals are primarily responsible for the construction of modern coral reefs in that they initiate reef construction and provide the basic framework of reefs. However, the activities of marine algae (chapter 6) are essential for subsequent reef formation and stabilization. Technically, hard corals are cnidarians (Phylum Cnidaria) belonging to the class Zoantharia, order Scleractinia. Individual coral animals are called *polyps*. Although the polyps belonging to some species of stony coral occur singly (the solitary corals), those belonging to most species of reef-building corals occur in large groups known as colonies. A single polyp that has developed from a fertilized egg founds each colony, but the founding polyp soon gives rise to numerous other polyps by a process called *budding*. This is a form of asexual reproduction involving the partial or complete separation of a group of cells from existing coral tissue and the formation of a new polyp from the separated cells.

Essentially, each coral polyp has the form of a hollow cylinder, sealed at one end (the base) and bearing a number of tentacles surrounding an opening (the mouth) at the other. The tentacles are capable of extension and contraction. The region in the vicinity of the mouth upon which the tentacles are borne is called the *oral disc*. Preliminary digestion of foodstuffs taken in through the mouth occurs within the stomach cavity, or coelenteron. This cavity is subdivided by a series of radiating vertical partitions (see fig. 3) called *mesenteries*. These are attached above to the inner surface of the oral disc, but their lower margins are free. The cells of the vertical edge of each mesentery constitute the so-called *cnidoglandular band*, and many of these cells are responsible for secreting enzymes that initiate digestion of food. At the lower margin of each mesentery each band is attenuated to form a convoluted, whip-like *mesenterial filament*, which assists in

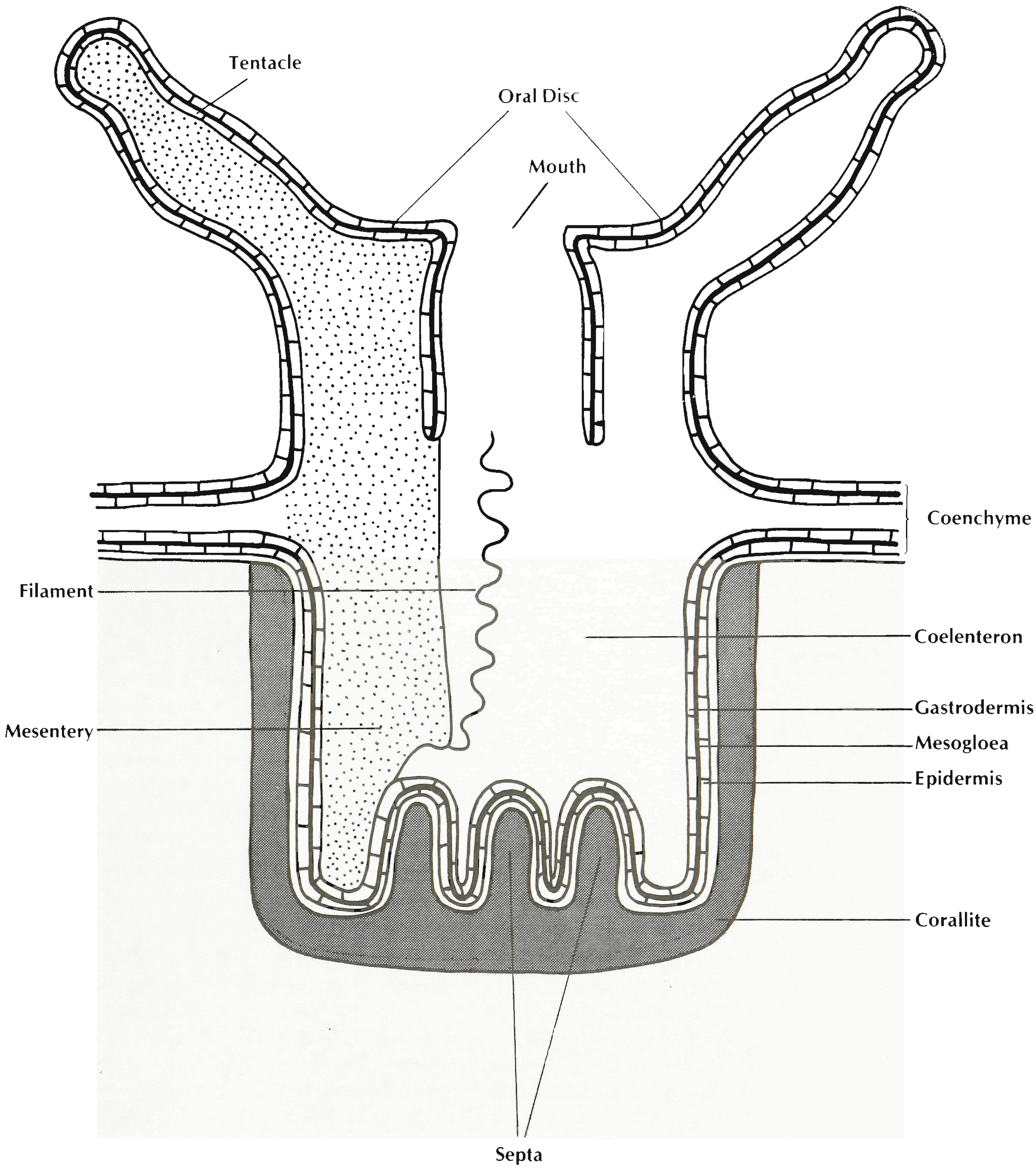


Figure 3. Vertical section of a coral polyp passing through one of the mesenteries.

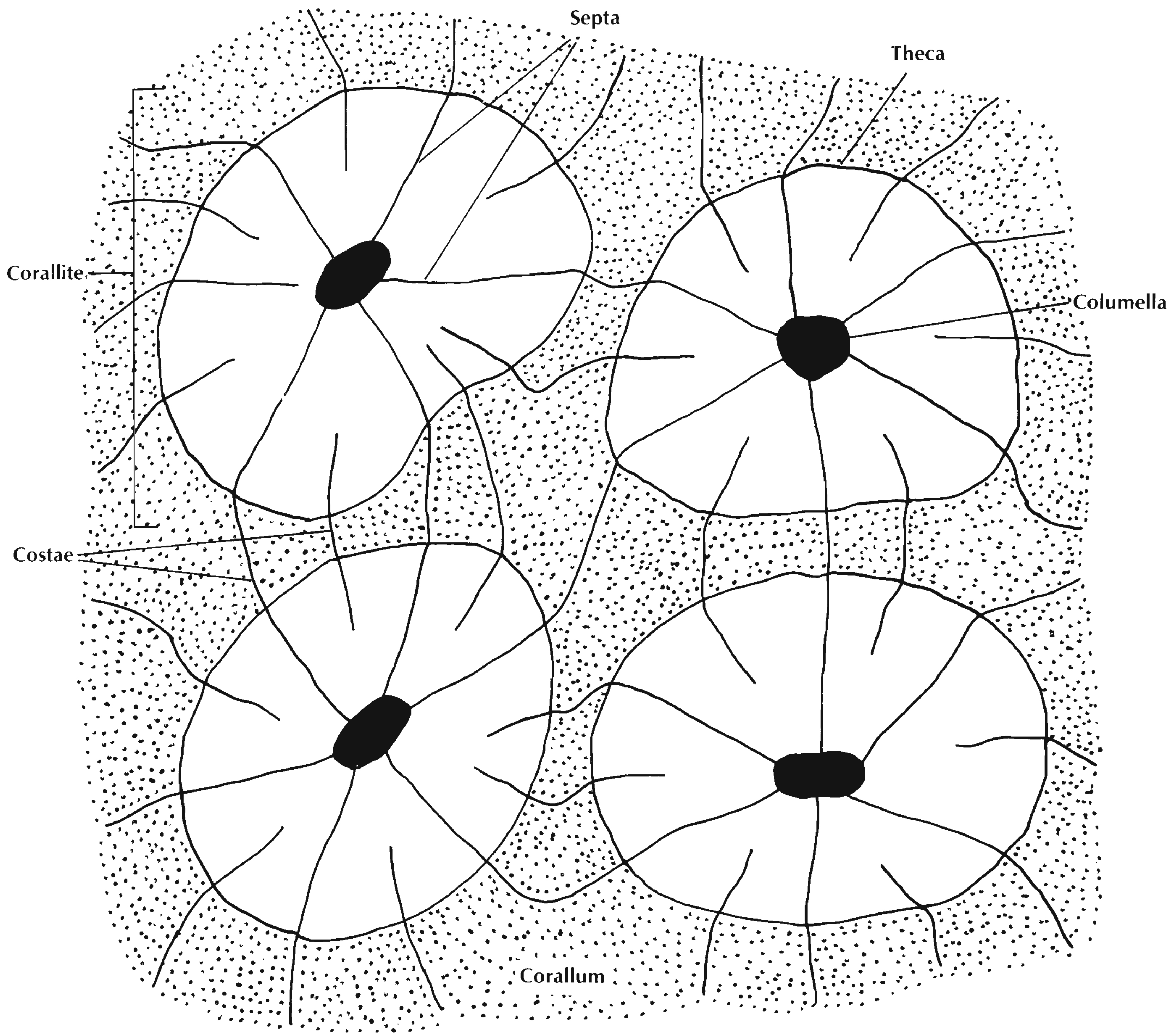


Figure 4. Portion of the surface of a corallum viewed from above and showing four corallites connected by costae. Note that some of the septa of each corallite do not extend as far as the central columella.

prey capture (since the tip can be protruded through the mouth) and assists also in subduing struggling prey brought into the coelenteron. A layer of cells (the *gastrodermis*) lining the coelenteron absorbs partially digested fragments of food, and digestion is completed in minute sac-like vacuoles within these cells. The cell layer on the outside of the polyp is called the *epidermis*. Cells belonging to this layer in the region of the polyp near the tentacles and on the tentacles themselves bear motile hair-like structures termed *cilia*, and frequently these cells also produce mucus. The gastrodermis and epidermis are separated by a third layer, the *mesogloea* which has a jelly-like consistency.

A protective skeleton of lime (calcium carbonate) called a *corallite*, which typically assumes the form of a cup with a number of radiating vertical partitions (called *septa*) arising from the basal plate of the cup, is secreted by regions at and near the base of each polyp. The polyp base is forced into folds by the septa, which are frequently fused at their inner ends to form a central axial structure termed the *columella* (see fig. 4). Continued secretion of calcium carbonate by basal regions of the polyp causes the septa to increase in height and push the polyp outwards within the tubular walls constituting the *theca* of the corallite (see fig. 5). At intervals, a partition forms at the outer ends of the septa and constitutes a new basal plate for polyp attachment. Thus the polyps are pushed outwards as the coral skeleton increases in size.

Individual polyps of a colony are interconnected by a lateral extension of the polyp walls called the *coenchyme*. This consists of the same cell layers (epidermis and gastrodermis) as the polyps and contains a cavity continuous with the coelenteron of each polyp. The lower surface of the coenchyme secretes that part of the skeleton occurring between adjacent corallites. Lateral extensions of septa called *costae* also occur in some species. In the branching corals belonging to genera such as *Acropora* and *Montipora*, the coenchyme is so thin that the coral skeletons appear exposed in life; in others, such as the brain corals, the coenchyme is quite thick. In a number of coral families the whole skeleton is much perforated, so that adjacent polyps are interconnected by way of these pores. These corals are known as the *perforate corals*, as opposed to the *imperforate corals*.

It should be noted that the coral polyps always remain on the surface of the coral skeleton (the *corallum*) and that they do not increase in size as the corallum increases in size. Although the average diameter attained by a coral polyp is only about 1 centimetre, the total skeletal material secreted by all the polyps and the coenchyme of a colony may be very bulky. Indeed, the colonies of some species of branching corals often form immense submerged forests, and single colonies of non-branching (termed *massive*) corals may eventually weigh several hundred tonnes. Colonies of these massive corals frequently have a hemispherical shape. However, the shape of a coral

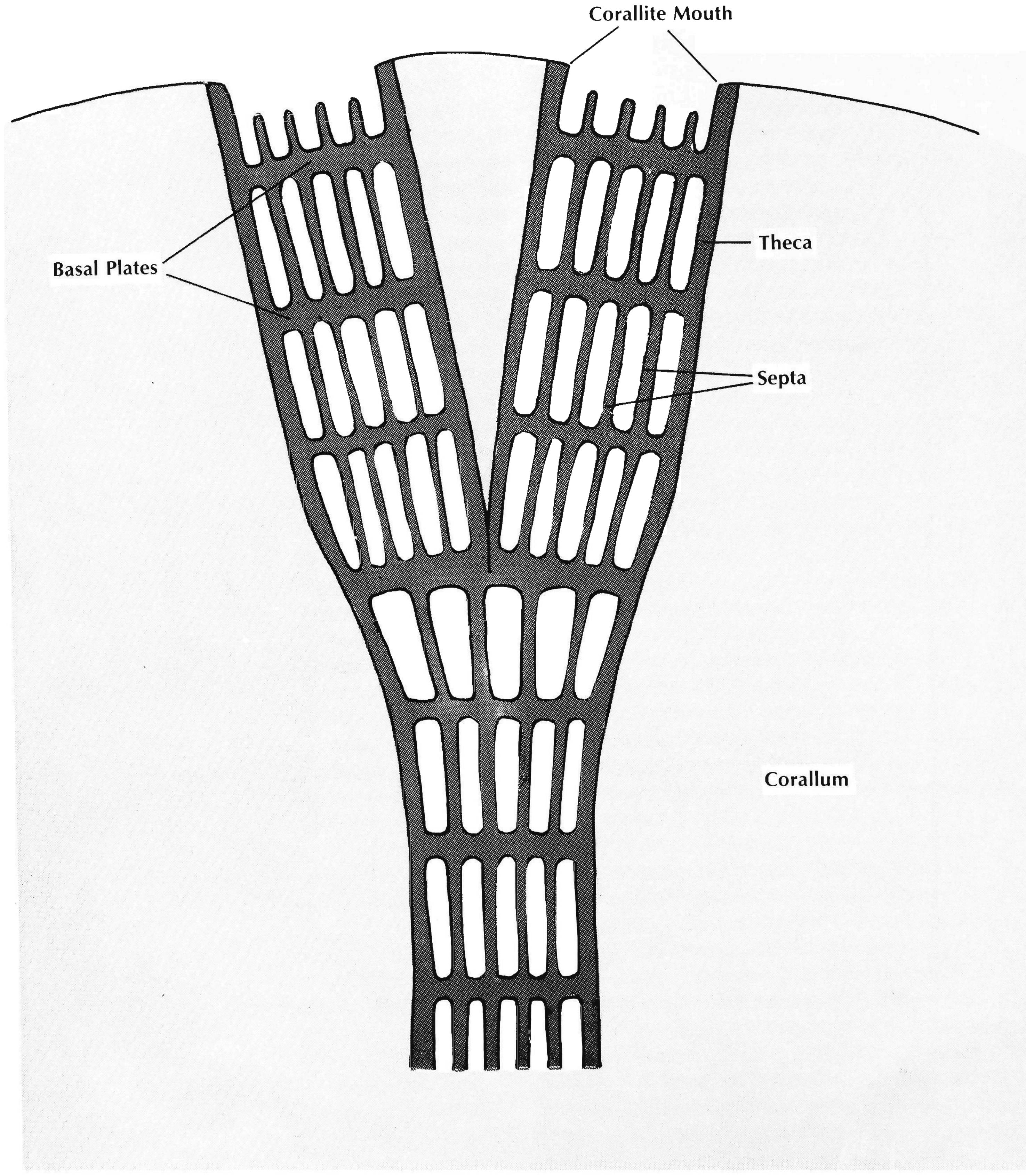


Figure 5. Section through two adjacent corallites.

colony varies greatly, not only from species to species but often also within the same species, some colonies showing subtle changes in form as a result of differences in environmental conditions to which each colony is exposed. Nevertheless, colonies belonging to each major group of coral usually have a characteristic shape. Differences in polyp size, in the ways in which budding occurs, and in the structure of the skeleton are principally responsible for differences among the major groups.

The polyps of some corals (e.g., the genera *Favia* and *Goniastrea*) are very large; those of others (e.g., the genus *Porites*) are small. Buds that give rise to new polyps may form in the coenchyme between pre-existing polyps and give rise to widely spaced polyps, as in the genus *Galaxea*. Buds arising on opposite sides of the oral disc (see diagram) may give rise to contiguous polyps, as in the genus *Favia*. If buds arise on the same side of the oral disc of a polyp, branching may occur, as in the genus *Acropora*. Alternatively, the polyps may be confluent and confined to depressed rows as in the "brain corals" exemplified by the genus *Platygyra*. In these corals the incomplete polyps in the depressed rows share a common fringe of tentacles and their corallites are confluent. Differences in the type of budding that occurs are of course reflected in the structure of the skeleton, which is used as the principal basis for classifying corals. In addition, in some groups of coral there are deletions from (e.g., loss of theca) or additions to (e.g., a double theca) the basic structure of the skeleton described earlier. In some groups, rods link the septa and may form the walls of the corallite.

The substratum, to which most reef corals attach, is semi-consolidated rubble overlying the limestone core of the reef, but there are some species, including many of the solitary corals (e.g., the mushroom corals belonging to the genus *Fungia*), that are free-living when adult.

Over three hundred species of coral occur in Great Barrier Reef waters. Most species found there belong to one of the families and genera of coral mentioned in the following list.

Families of Corals found on the Great Barrier Reef

Thamnasterids (Thamnasteridae) have minute corallites which lack thecae; costae extend between adjacent corallites. The small polyps bear less than twelve tentacles in a single ring. Only one living genus is recognized. Colonies of this genus form small rounded clumps or small clumps with stubby branches that bear irregular grooves. They occur on reef flats and in the back-reef areas on the Great Barrier Reef but appear to be somewhat rare. Colours exhibited are grey, brown, or purplish red.

Genus represented: *Psammocera*.

Astrocoeniids (Astrocoeniidae) have small corallites with prominent projecting septa and columellae. They are characterized by the possession of pillar-like structures that project from the surface of the corallum between adjacent corallites. Polyps rarely have more than twelve tentacles, which are arranged in a single ring. Only one living genus has been found in the Indo-West Pacific region. Small encrusting colonies belonging to this genus are occasionally found growing in reef crevices on the Great Barrier Reef.

Genus represented: *Stylocoeniella*.

Pocilloporids (Pocilloporidae) form branching or lobed colonies consisting of small, deep-set corallites which are usually arranged in rows. Each corallite possesses a columella, but the septa are often rudimentary. In the genus *Madracis*, which appears to be rare on the Great Barrier Reef the septa occur in multiples of eight or ten rather than multiples of six as in other corals. In the genus *Stylophora*, which is usually well represented on reef flats, reef slopes, and in lagoons, the short, slightly flattened branches of a colony are prickly to the touch because hoods arch over the openings of the corallites. In the genus *Palauastrea*, found in sheltered areas of fringing reefs, spines occur on the surface of the corallum between adjacent corallites. The genus *Seriatopora* is often referred to as "needle-coral" because some of the terminal branches of a colony are very fine. Colonies of *Seriatopora* are found in sheltered areas, particularly on reef flats. Species of *Pocillopora* sometimes occur commonly on reef flats and in lagoons. Pocilloporids range in colour from blue or purple to green, brown, and pink. The polyps are small and each bears a single ring of tentacles.

Genera represented: *Pocillopora, Seriatopora, Stylophora, Palauastrea, Madracis*.

Acroporids (Acroporidae). Small cylindrical corallites with up to twelve simple septa are present in the greatly perforated corallum of an acroporid, which has no columella. The polyps usually bear less than twelve tentacles arranged in a single ring. Members of this family are the dominant corals in most areas of the Great Barrier Reef. Numerous species of the genus *Acropora* occur there. These show great variation in growth form. Some form large branching colonies known as staghorn corals, some form low bushy clumps, some form platelike or tabular structures composed of interlocking branches, and a few are encrusting. Corallites protrude from the corallum, and in branching forms a single corallite may run the length of a branch and open at the tip while the other corallites are radially arranged. Colonies belonging to the genus *Montipora* usually form thin, leafy plates (sometimes arranged in conical stacks) or irregular encrustations; the surface of each corallum has a rough texture because projections arise between adjacent corallites. Likewise, numerous low spikes protrude from the coralla of colonies belonging to the genus *Astreopora*. The rounded openings of the corallites, which have short septa, also protrude from the coralla of the hemispherical colonies formed by this genus. The colours of acroporids range from purple and blue to green, yellow, brown, and pink.

Genera represented: *Acropora, Montipora, Astreopora.*

Agariciids (Agariciidae). In members of the family Agariciidae the thecae are usually absent or poorly developed and the fine septa extend between adjacent corallites as costae. Rods are usually present between adjacent septa. The polyps have more than two rings of tentacles. Colonies belonging to the genus *Pavona* are either encrusting or composed of clusters of small lobed or vertical plates. On close examination a starlike arrangement of the septa of each corallite will be apparent. Colonies are green or brown and occur on reef flats and reef slopes. Thin platelike colonies are formed by members of the genus *Leptoseris*. Concentric ridges involving systems of corallites occur in several regions of the plate. Colonies are found in shaded parts of the reef, particularly in caves and under overhangs. They are usually grey or greenish. In the genus *Gardinioseris*, colonies are encrusting or columnar. The surface of each colony is markedly striated because of the presence of parallel ridges and depressions. Colonies are brown, purple, and yellow and are found occasionally on reef flats and reef slopes. In the genus *Coeloseris* each corallite is defined by a wall (theca) and lacks a columella. Colonies are usually pale green, yellow, or brown and occur, sometimes commonly, on reef slopes. Colonies of the genus *Pachyseris* form thin, circular plates, the surfaces of which bear concentric ridges and valleys. The corallites are minute. Colonies average 20 centimetres in diameter and are grey or brown. They occur on upper reef slopes, particularly near surge channels, but are not commonly encountered.

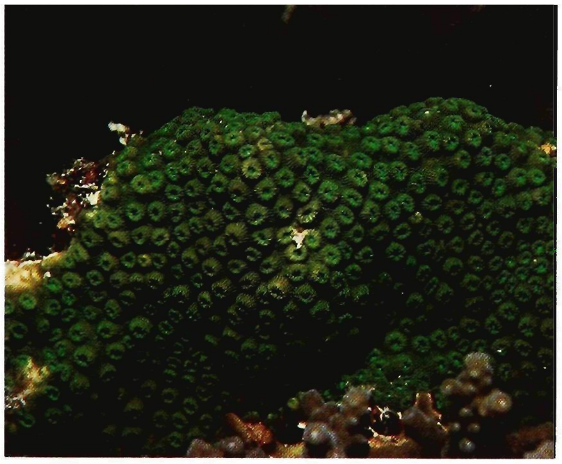
Genera represented: *Pavona, Leptoseris, Gardinioseris, Coeloseris, Pachyseris.*

Siderastreids (Siderastreidae). The corallites of siderastreids are small and crowded with septa which bear serrations on their upper margins. Rods link adjacent septa and form the corallite wall. Costae are present. The small polyps have more than two rings of tentacles. Colonies belonging to the genus *Pseudosiderastrea* usually appear as thick, encrusting masses. The corallites have polygonal openings, and the septa


10


11

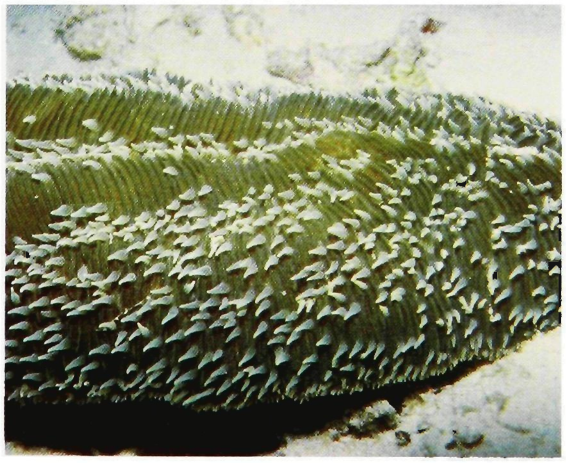

12


13

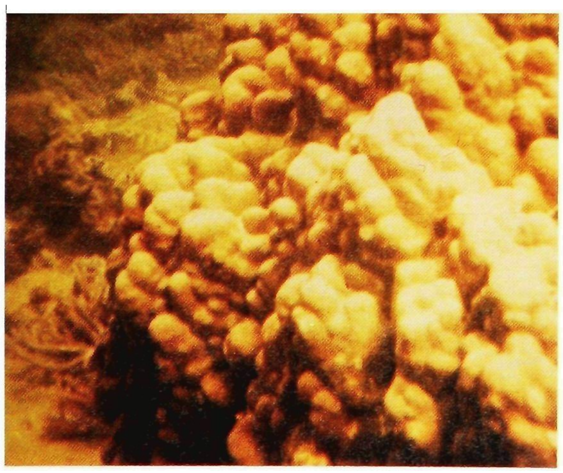

14


15


16


17


18


19


20


21

bear small spines. Colours exhibited are pale grey or pink. Rounded or encrusting colonies are formed by members of the genus *Coscinarea*. Low ridges surrounding groups of corallites are found on the surface of the corallum. Colonies range from brown to purple in colour and are usually found on reef slopes.

Genera represented: *Pseudosiderastrea, Coscinarea*

Fungiids (Fungiidae) are largely non-attached corals that may be disclike or elongated. While most species are colonial, a few are solitary. The corallites are greater than 2 millimetres in diameter and have prominent septa which are united by rods and bear numerous perforations; costae are present. The polyps have more than two rings of tentacles. All fungiids are attached to the substratum by a stalk when young, but the stalk breaks in those species that are non-attached when adult.

The common "mushroom" corals belonging to the genus *Fungia* each consist of a solitary polyp between 5 and 15 centimetres in diameter. The corallite, which is usually somewhat oval in outline with a convex upper surface, has a large number of vertical radiating septa. Mushroom corals occur commonly on reef flats and are usually brown or greenish-brown in colour. Tentacles are usually retracted during daylight hours.

In the genus *Heliofungia* the solitary polyps are large (up to 20 centimetres in diameter). Their thick tentacles are up to 8 centimetres in length and are nearly always fully extended. They occur on reef flats and in lagoons.

Members of the genus *Cycloseris* are solitary non-attached corals that resemble *Fungia* but are only about 2 centimetres in diameter. A species of *Cycloseris* that is green, grey, or brown in colour is found on sandy areas in deeper water at the periphery of reefs.

The smallest representatives of the solitary fungiids belong to the genus *Diaseris*. They average only 1 centimetre in diameter. Each is flat and disc-shaped, although formed of several wedge-like segments. Specimens occur on sandy bottoms adjacent to reefs and have remarkable powers of locomotion that have resulted in the term "acrobatic coral" being applied to the genus.

Members of the genus *Lithophyllon* remain attached to the substratum when adult. They are colonial and have a foliate growth pattern. They occur in lagoons and other sheltered situations.

Representatives of the colonial fungiid *Podobacia* also remain attached to the substratum when mature. Colonies occur as sheets, which often assume a vaselike form. These are brownish and occur occasionally in lagoons and on sheltered reef slopes.

The colonial genus *Herpolitha* has an elongated, twisted shape (averaging about 25 centimetres in length) and is known commonly

Facing page

Illustration 10
Needle coral, *Seriatopora hystrix*.

Illustration 11
A forest of staghorn coral, *Acropora* sp.

Illustration 12
A tabular or plate coral, *Acropora hyacinthus*.

Illustration 13
Portion of a colony of *Astreopora myriopthalma*.

Illustration 14
Adjacent colonies of a species of *Montipora*.

Illustration 15
Part of a colony of a species of *Pachyseris*.

Illustration 16
A mushroom coral, *Fungia actiniformis*.

Illustration 17
Portion of a slipper coral, *Herpolitha limax*.

Illustration 18
Expanded polyps of portion of a colony of *Goniopora tenuidens*.

Illustration 19
Portion of a colony of the massive coral *Porites lutea*.

Illustration 20
The small expanded polyps of portion of a colony of *Porites lutea*.

Illustration 21
Portion of a colony of *Favites abdita* showing the large greenish retracted polyps.

as the "slipper coral". A deep groove runs longitudinally along the centre of the upper surface. Septa are prominent. The colony is free, brownish, and occurs in lagoons and in the deeper water at the edges of reefs.

Members of the colonial genus *Herpetoglossa* closely resemble those of *Herpolitha* but differ in septal characteristics. For example, the main septa of *Herpetoglossa* may run from the central groove to the perimeter

Expanded polyps of the ahermatypic coral *Tubastrea aurea*.

of the corallum, but those of *Herpolitha* never do so. Specimens of *Herpetoglossa* occur frequently in lagoons.

Members of the genus *Polyphyllia* are free-living and colonial. They resemble *Herpolitha* but are domed and appear smoother. Also, they lack a central furrow. Numerous corallite mouths are apparent in the corallum. This fungiid occurs in lagoons and on reef slopes and is brown in colour.

Colonies belonging to the genus *Halomitra* have a deep concavity in the undersurface and are often bell-shaped. There is a central depression from which septa radiate, but these septa pursue a sinuous and interrupted course.

Free-living colonial fungiids belonging to the genus *Parahalomitra* resemble an inverted dish and are known as "basket corals". Numerous corallite openings are apparent. Septa are well developed and give the corallum a rough appearance. The coral averages about 25 centimetres in diameter, is brownish, and occurs in lagoons and in deeper water at the periphery of reefs.

Members of the colonial genus *Sandolitha* have a similar appearance to those of the genus *Halomitra* but are more elongate. Also, the septa of *Sandolitha* have large serrations that are covered with granules and differ from those of *Halomitra* structurally.

Genera represented: *Fungia, Heliofungia, Cycloseris, Diaseris, Lithophyllon, Podabacia, Herpolitha, Herpetoglossa, Polyphyllia, Halomitra, Parahalomitra, Sandolitha.*

Poritids (Poritidae). Numerous contiguous corallites form the colonies of poritids. The septa are perforated by minute pores and some are linked by rods. The polyps have more than two rings of tentacles, which are capable of great extension. Colonies of the genus *Porites* exhibit a great variety of shape, but there is a tendency towards the formation of circular, flattened structures (micro-atolls) on reef flats and dome-like structures in deeper water. Some colonies form stubby branches. Sizes of colonies range from a few centimetres to over 5 metres in diameter. The openings of the corallites are very small, and colonies have a smooth appearance. Species belonging to this genus may be found in most areas of a reef and are often common. Colours range through green, grey, brown, pink, and mauve. The coralla of colonies of the genus *Goniopora* are rounded and resemble small colonies of *Porites*. However, each corallite of *Goniopora* has twenty-four septa compared with twelve in *Porites*. In living colonies the elongate polyps, which have twenty-four tentacles in a single ring, are nearly always extended, making identification easy. They are brown, green, or grey in colour. Colonies occur commonly on reef flats and reef slopes. Members of the genus *Alveopora* resemble *Goniopora*, but the colonies are very small and the corallites are relatively large. The septa arise from the walls rather than the floor of each corallite. Colonies occur on the reef slope and have a greyish colour.

Genera represented: *Porites, Goniopora, Alveopora.*

Faviids (Faviidae). The corallites of faviids are large and have prominent septa with serrations on their edges which project above the corallite mouth at their junctions with the thecae. The corallites have sturdy walls; however, in some genera, groups of corallites occur in series and lack internal walls. The polyps usually have more than two rings of tentacles. In the genus *Favia* the corallites are large (averaging 1 centimetre in diameter), with spherical or irregularly shaped surface openings. They are clearly separated one from another. Colonies are usually hemispherical, but sometimes encrusting, and average about 20 centimetres in diameter. Most are brown or green and are common on reef flats and reef slopes and in lagoons.

Colonies belonging to the genus *Favites* are similar in shape and size to those of *Favia.* However, the corallites share a common wall and are usually polygonal in shape. Polyps are brown, green, or brown with green centres. Colonies occur fairly commonly on reef flats and reef slopes and in lagoons.

In the genus *Hydnophora* the shared walls of adjacent corallites project from the corallum as cones, making members of this genus easy to recognize. Colonies are usually less than 20 centimetres in diameter and may be branching, rounded, or encrusting. They are coloured brown, grey, or green and occur on reef flats and reef slopes and in lagoons.

Small, rounded colonies are formed by representatives of the genus *Montastrea.* The corallites vary in size, have circular openings, are well separated one from another, and project slightly from the surface of the corallum. Costae are present. The brownish colonies occur on reef flats but are not commonly encountered.

Members of the genus *Plesiastrea* resemble those of *Favia* but the openings of the corallites are rounder. Also, very small corallites are found among the larger ones. Colonies are rarely more than 25 centimetres in diameter, are brown, and are found on outer reef flats, reef crests and upper parts of reef slopes.

Small, rounded colonies, rarely exceeding 20 centimetres in diameter, are formed by members of the genus *Cyphastrea.* The appearance of the corallites of this genus resembles those of *Montastrea;* however, granules occur on the surface of the corallum among the corallites in *Cyphastrea.* Colonies are brownish and occur, often in small clusters, on reef flats, reef crests, and upper reef slopes.

In the genus *Diploastrea* the septa of each corallite are thick peripherally and thin internally where they join a prominent columella. Very large dome-shaped colonies, usually pale cream in colour, are formed.

The colonies may occur in a variety of situations, ranging from the exposed reef front to protected back-reef areas.

Colonies belonging to the genus *Leptastrea* resemble those of *Montastrea*, but the corallites of *Leptastrea* are crowded together, conferring a honeycomb-like appearance on the corallum. Also, costae are lacking in *Leptastrea*. Colonies are brown or purplish and occur on reef flats and reef crests.

In the genus *Goniastrea*, groups of corallites are bounded by an outer calcareous wall which is shared by groups of adjacent corallites. Short, sinuous grooves where the polyps are located in life are thereby formed. Each polyp in a group has a separate mouth. *Goniastrea* species form hemispherical colonies averaging about 15 centimetres in diameter. The colonies are brown, green, or grey and occur commonly on reef flats and reef slopes and in lagoons.

Species belonging to the genera *Platygyra* and *Leptoria* constitute the so-called brain corals. In these corals, groups of corallites are linked in series and are bounded by an outer calcareous wall. This wall is shared by adjacent corallite groups. Thus a system of sinuous ridges and valleys is formed on the surface of the corallum. The polyps belonging to a series have a common mouth. Rounded colonies of *Platygyra* occur on reef.slopes and outer reef flats and in lagoons. They average about 2 metres in diameter and are coloured green, brown, or grey. Members of the genus *Leptoria* closely resemble *Platygyra* but have a continuous columella running along the floor of each sinuous groove. Colonies of *Leptoria* are green or brown and occur on reef flats and reef slopes and in lagoons.

Corals belonging to the genus *Oulophyllia* have a corallum with higher ridges and deeper and wider valleys than in the genera *Platygyra* and *Leptoria*, which they otherwise resemble. Colonies of *Oulophyllia* are light green or light brown and occur occasionally on reef slopes.

Colonies of *Echinopora* take the form of folded plates or branching structures averaging about 25 centimetres in diameter. The large projecting corallites have rounded openings. Spikes or ridges are found on the surface of the corallum among the corallite openings. Colonies are brown or green and occur commonly on reef slopes and occasionally in outer regions of reef flats.

Genera represented: *Favia, Favites, Hydnophora, Montastrea, Plesiastrea, Cyphastrea, Diploastrea, Leptastrea, Goniastrea, Platygyra, Leptoria, Oulophyllia, Echinopora.*

Trachyphyllids (Trachyphyllidae). The upper edges of most septa bear prominent lobes towards the centre of each corallite in members of the family Trachyphyllidae. Small serrations occur on septa at the margins of each corallite. Only one genus, *Trachyphyllia*, is represented on the Great Barrier Reef. It contains free-living colonial corals

composed of a small number of polyps. Colonies average 10 centimetres in diameter and are found on sand or among rubble near the bottom on reef slopes, particularly on the lee side of reefs. Colours exhibited are green, brown, reddish or grey.
Genus represented: *Trachyphyllia.*

Mussids (Mussidae) may be solitary or colonial and have very large fleshy polyps and correspondingly large corallites in the corallum. The septa exhibit markedly serrated margins, conferring a spiky appearance on the corallum. The polyps usually have more than two rings of tentacles. Mussid features are well shown by the domelike colonies of *Acanthastrea,* which attain a size of about 25 centimetres in diameter. Corallites of the genus *Lobophyllia* are large (averaging 3 centimetres in diameter), well separated from one another, and often protrude in stalklike fashion from the corallum, which may be 1 metre or more in diameter. A similar size is attained by colonies of the genus *Symphyllia.* In this genus the walls of groups of adjacent corallites fuse, producing a convoluted appearance reminiscent of brain corals. Small tufts of erect cylindrical corallites arise from the corallum in the genus *Blastomussa.* The colonial mussids occur in the outer zones of reef flats in lagoons, channels in back-reef areas, and on reef slopes. Colours are mostly greens and browns. Corals belonging to the mussid genera *Scolymia* and *Cynarina* are solitary. The corallite of *Scolymia* averages about 5 centimetres in diameter and resembles that of *Lobophyllia.* Species belonging to this genus are commonly found attached to cliff faces and to deeper sections of reef slopes. Polyps are usually coloured green or orange. The corallite of *Cynarina* is about 4 centimetres in diameter. The coral may be attached to the deeper reef slopes in protected areas or free on the sea-floor near reefs. The polyp is pale brown.
Genera represented: *Acanthastrea, Lobophyllia, Symphyllia, Blastomussa, Scolymia, Cynarina.*

Merulinids (Merulinidae). In the small merulinid family the corallites are always linked to form a series of rows which fan out towards the edge of the colony. The septa are thick and have jagged upper edges. The polyps have more than two rings of tentacles. In the genus *Merulina,* colonies usually occur as thin plates covered by radiating ridges. Raised growths often occur in central areas of the colonies. Usually colonies are brown, but occasionally they are greenish and are found on reef flats and reef slopes. The general appearance of the corallites in the genus *Clavarina* resembles that of the corallites of *Merulina,* but colonies of *Clavarina* form branching structures brown or grey in colour and sometimes more than 1 metre in height. They are found in lagoons and in back-reef areas but are somewhat rare.

Facing page
Large fleshy polyps belonging to a member of the family Mussidae (*Lobophyllia corymbosa*).

Small, rounded colonies of the genus *Scapophyllia* are found occasionally on reef slopes in waters of the Great Barrier Reef. They are usually grey or brown and resemble *Merulina* in the structure and arrangement of corallites.

Genera represented: *Merulina, Clavarina, Scapophyllia.*

Ivory corals (Oculinidae) form branching or hemispherical colonies characterized by the presence of the well-separated, round openings of the corallites which project from the corallum. The corallites have a spiky appearance because the septa project above the thecae of the corallites. Polyps with more than two rows of tentacles are present. In the genus *Galaxea*, colonies are small, usually hemispherical or lobed, with corallites about 5 millimetres in diameter projecting 5 to 10 millimetres above the corallum. Cream-coloured, green, or brownish colonies occur on outer reef flats and upper reef slopes but are not common. Only a single species of the genus *Acrhelia (A. horrescens)* is known. It resembles a branching form of *Galaxea*. Small clumps of this elegant coral occur on outer reef flats and upper reef slopes. Colonies are brown or grey.

Genera represented: *Galaxea, Acrhelia.*

The corallum of a hemispherical colony belonging to the faviid genus *Favia*. Individual corallites each with a series of radiating septa are apparent.

Pectinids (Pectiniidae) are colonial and have large polyps. Adjacent corallites fuse and have indistinct walls. The margins of the septa are irregularly toothed. Extensions of the septa (costae) are apparent in the intervals between adjacent corallites and confer a lined appearance on the corallum. Polyps have more than two rings of tentacles. Four genera belonging to this family have been recorded from the Great Barrier Reef. In the genus *Pectinia* the large fragile corallites are irregularly arranged, giving the corallum a leafy appearance which has led to its common name "carnation coral". Colonies are usually about 25 centimetres in diameter but may exceed 1 metre. They are brown or grey in colour and occur in lagoons and on reef slopes. In the genus *Echinophyllia* the colonies form thin sheets that are usually encrusting and have a rough appearance. The lines formed by the costae are prominent. Colonies are usually green or brown, occur on reef slopes and average about 20 centimetres in diameter. Corals belonging to the genus *Mycedium* resemble those belonging to the genus *Echinophyllia*, but the corallites open at an oblique angle to the surface of the corallum. Colonies of *Mycedium* are brown or green, average about 20 centimetres in diameter, and usually occur in the deeper waters of reef slopes. Colonies of the genus *Oxpora* consist of large, thin plates which may overlap. The corallites are well separated and each has a prominent columella. Perforations occur in the corallum in the spaces between adjacent corallites. Living colonies are brown, green, or reddish and occur in lagoons and on reef slopes.

Genera represented: *Pectinia, Echinophyllia, Mycedium, Oxypora.*

Caryophyllids (Caryophyllidae). Both solitary and colonial corals are included in the family Caryophyllidae. The septa are smooth and platelike. Polyps have more than two rings of tentacles. The corallites of the genus *Euphyllia* are elongate and occur singly or in rows. Their openings have irregular shapes. The prominent septa project above the openings. The polyps are large, with numerous tentacles. Colonies are usually grey or brown and occur on reef slopes and in lagoons. They sometimes exceed 1 metre in diameter. Only one species belonging to the genus *Catalophyllia*, which is closely related to *Euphyllia*, is known. Its corallites occur in rows in sinuous depressions. The polyps have fleshy grey tentacles and green oral discs. Large colonies are domed and up to 1 metre in diameter. They occur on reef slopes and in lagoons. Small solitary corals, only about 1 centimetre in diameter, are included in the genus *Heterocyathus*. Each coral is always associated with a gastropod shell containing a sipunculid worm (see chapter 9). The worm moves the coral about in the sand in the vicinity of reefs. Colonies of the genus *Plerogyra* have an appearance similar to those of *Euphyllia*, but the corallites of *Plerogyra* are united at their bases and have very large projecting septa. The greyish colonies occur chiefly on vertical faces or in caves and crevices in protected areas. In members of the genus *Physogyra*, which also resemble those of *Euphyllia*, the corallites are united at the tops of the thecae. Colonies are grey or brown and occur on reef slopes.

Genera represented: *Euphyllia, Catalophyllia, Heterocyathus, Plerogyra, Physogyra.*

Dendrophyllids (Dendrophyllidae). The corallites of colonial members of the dendrophyllid family are large, protuberant, and well spaced. Rods link adjacent septa. The corallum is very porous. The polyps have several rings of tentacles. Some genera do not have symbiotic algae in their tissues and are termed *ahermatypic*. Colonies of the genus *Turbinaria* occur as crenated plates, often with a vaselike appearance. The large, well-spaced corallites are confined to the upper surfaces of the otherwise smooth plates. Colonies are coloured brown, yellow, green, or grey and are found in lagoons and on the lower reef slopes. Corals belonging to the genus *Dendrophyllia* exhibit a treelike growth form, with branches growing from each side of the main stems. The corallites are large, and each has a prominent columella. Brown, green, orange, and black are among the colours displayed. These so-called "tree corals" grow on reef slopes in shaded situations such as caves and under overhangs. They are ahermatypic, as are corals belonging to the genus *Tubastrea*. These occur as clusters of tubular corallites growing from a common base and are found in similar habits to those occupied by *Dendrophyllia*. Colours shown are bright orange, yellow, and green. Members of the genus *Heteropsammia* are known as "button corals". They are either solitary or consist of colonies of a very few polyps. They are free-living, the base of each coral enclosing the tube of a sipunculid worm, which moves the coral about on the sandy bottom off the reef slope where it is occasionally encountered. Colours exhibited are brown, yellow, and green. Button corals are usually about 2 centimetres in diameter.

Genera represented: *Turbinaria, Dendrophyllia, Tubastrea, Heteropsammia.*

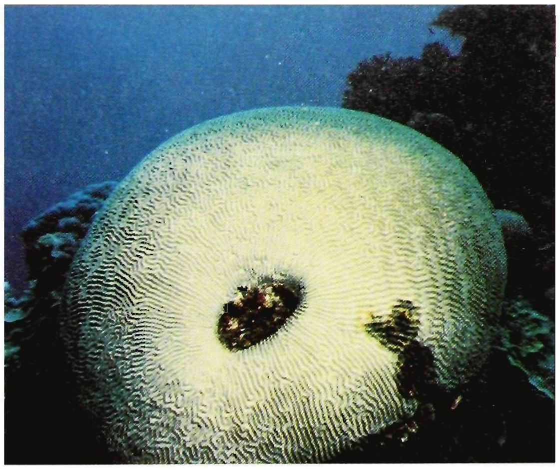
Physiology and Life Histories of Hard Corals

Various feeding methods are employed by coral polyps. One method is known as *tentacular feeding*. Polyps of most types of coral have retractile tentacles that are arranged in rows around their mouths (six to thirty tentacles per row depending on the species of coral involved). The tentacles are armed with batteries of minute organelles called *nematocysts* and *spirocysts*. Two types of nematocyst occur in corals.

Each is involved with the injection of a potent toxin into other animals, usually prey. There are spines associated with the hollow thread of these organelles. The spirocyst contains an unarmed thread which, when discharged, produces numerous long slender fibres that appear to entangle prey. Corals such as species of *Dendrophyllia*, which live in shaded areas on reefs, and large-polyped, reef-forming corals such as species belonging to the genera *Favia, Goniastrea,* and *Lobophyllia* feed by means of tentacles whenever the opportunity to do so is provided. Their prey is trapped and immobilized by the nematocysts carried by the long tentacles, which also convey prey to the mouth.

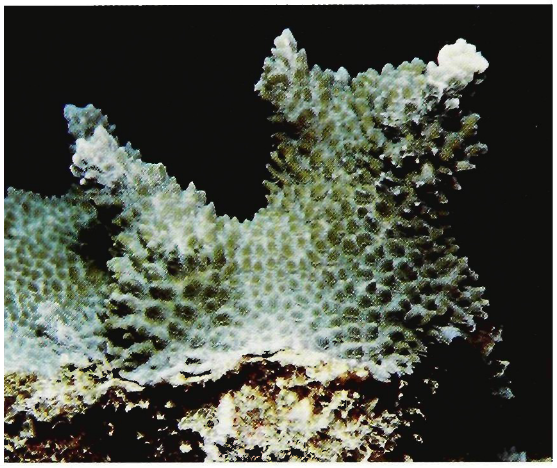
Another major method of feeding employed by corals is termed *ciliary-mucoid feeding*. The epidermis (outer covering) of corals contains cells that possess minute cilia. In most corals these cilia are abundantly represented and form ciliary pathways that run the length of the polyp. They may also run from base to tip of tentacles and to the mouth area. Mucus is secreted by many cells of the epidermis, especially cells near the mouth. Particulate material (minute animals, clumps of bacteria, and detrital matter) present in the water is enmeshed in the sticky mucus if the material impinges on the surface of a polyp. The material is then moved by ciliary currents to the tentacles, where sorting of the material leading to acceptance or rejection occurs. Material that is accepted passes by means of ciliary currents to the mouth, where it is swallowed; material that is rejected passes by the same means to regions where it can be ejected from the polyp. Ciliary currents are also involved in removing sediment from polyps, and they have this role almost exclusively in those species that feed primarily by tentacles. Species belonging to genera such as *Merulina* and many mushroom corals (Fungiidae) have tentacles that are too small to bring food to the mouth, and they rely heavily on ciliary-mucoid feeding of the type just described. Feeding of this type is also engaged in extensively by representatives of many genera of corals, including *Seriatopora, Stylophora, Leptastrea, Cyphastrea, Porites, Pavona,* and *Psammocera*.

Another type of feeding is by means of mesenterial filaments. As noted earlier, the free margins of mesenteries are thickened to form whip-like mesenterial filaments. These bear enzyme-secreting cells and nematocysts. The mobile filaments may be thrust through the mouth or, in some species, through permanent or temporary holes in the body of the polyp. Feeding by extrusion of mesenterial filaments is particularly common in species belonging to the families Mussidae and Faviidae. In some corals the filaments are used to stir up detritus in the vicinity of the corals and to trap particulate matter. Species of *Pachyseris* lack tentacles entirely. In this genus, particulate material enmeshed in mucus is moved by ciliary currents to the mouth of each polyp, where mesenterial filaments wrap around any struggling prey.


25


26


27


28


29


30

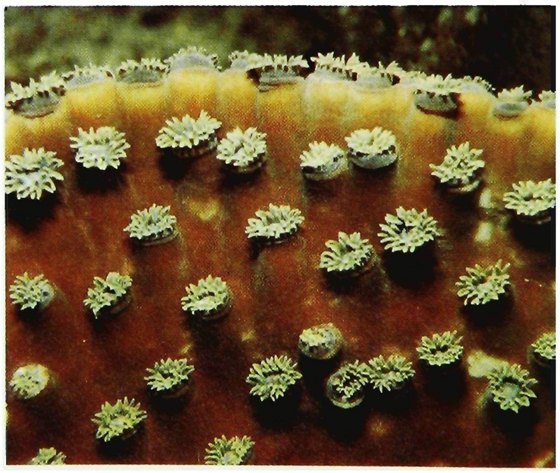

31


32


33


34


35


36

It has long been known that dissolved organic substances ranging from single amino acids and sugars to complex macromolecules are present in sea water. Corals certainly have the ability to take up organic substances directly from sea water, but the extent to which they engage in this type of activity generally is not known with certainty.

Yet another type of feeding involves the utilization by corals of materials produced by microscopic organisms called *zooxanthellae,* which live in the tissues (principally the gastrodermis) of corals. Zooxanthellae are the non-motile (encysted) stages of certain species of algae. Their association with corals is an example of symbiosis, where two organisms live in an association from which they derive mutual benefit. The algae are provided with living space and protection and a plentiful supply of basic nutrients such as phosphates and nitrates. The manner in which the coral polyps benefit is not so obvious, but there is now good evidence to suggest that they obtain part of their nutritive requirements from zooxanthellae. The algae possess chlorophyll pigments which enable them to use the energy of sunlight in the synthesis of organic materials. Some of the soluble products of this synthesis are released by the zooxanthellae, and some, at least, appear to be used in coral metabolism. However, the proportion of a coral's nutritive requirements that is provided by zooxanthellae is not yet known. It may be considerable, particularly in branching corals such as species of *Pocillopora,* where approximately half the biomass of the polyp consists of zooxanthellae.

As well as enabling them to cope more effectively with varying conditions of food availability, the abilities of corals to use several feeding methods and several types of food enable them to partition or share out the available food resources. Possibly large-polyped species specialize in plankton capture, small-polyped massive species specialize in ciliary-mucoid feeding, and branching acroporids that form canopies specialize in obtaining their nutrition from zooxanthellae.

Reef-forming corals do not grow below about 50 metres, and they flourish best in water shallower than 30 metres. It is probable that the depth to which these living corals grow is correlated with the light requirements of their contained zooxanthellae. As mentioned earlier, the symbiotic algae require light for photosynthesis. Although it appears likely that the zooxanthellae produce materials that provide nutrients for corals, they are of importance to corals in another major way. One of the structural features of reef-forming corals is their possession of heavy calcareous (limy) skeletons. It has been found that the amount of lime secreted by a coral colony varies over a twenty-four-hour cycle, much more being secreted during daylight than during darkness. Calcium uptake from sea water is fastest on a

Facing page

Illustration 25
A large hemispherical colony of the brain coral *Platygyra lamellina.* (The colony has been damaged in two places.)

Illustration 26
Portion of the surface of a colony of *Platygyra dadaelea.* The sinuous ridges and valleys characteristic of brain corals are well shown. The retracted tentacles of polyps line the valleys.

Illustration 27
Portion of the surface of a colony of *Oulophyllia crispa.* The mouths of individual polyps are apparent in the valleys.

Illustration 28
A colony of *Hydnophora exesa.*

Illustration 29
A portion of a colony of the massive coral, *Symphyllia nobilis.*

Illustration 30
A solitary coral belonging to the family Mussidae.

Illustration 31
Portion of a colony of *Merulina ampliata.*

Illustration 32
Portion of a colony of the ivory coral, *Galaxea fascicularis.*

Illustration 33
Portion of a colony of *Mycedium tubifex.*

Illustration 34
A colony of *Euphyllia* sp. showing the tubular corallites.

Illustration 35
A colony of *Tubastrea aurea* with most of the polyps retracted.

Illustration 36
Portion of a colony of a species of *Turbinaria* showing the well-spaced polyps.

clear, sunny day and is reduced by 50 per cent on a cloudy day and by 90 per cent in total darkness. In corals from which zooxanthellae have been removed, calcification rates are very low and independent of light intensity. It has been postulated that zooxanthellae facilitate deposition of calcium carbonate by participating directly in the chemical reactions leading to its formation or by producing organic material that acts as a framework on which the calcium carbonate is deposited. At any rate, corals containing zooxanthellae (the so-called *hermatypic* corals) are restricted to shallow water where sufficient light is available for photosynthesis by the zooxanthellae. Hermatypic corals are primarily responsible for reef building. Ahermatypic corals, since they do not possess zooxanthellae, are not restricted in their distribution by the need for light and may occur in very deep water (water over 5,000 metres in depth).

The daily variation in calcium carbonate deposition mentioned earlier leads to the presence of obvious bands interpreted as growth bands in the skeletons of some species of coral. J. W. Wells of Cornell University noted that there were about 360 bands in the space of a year's growth and suggested that the bands were daily growth increments. Interestingly, he noted that in several fossil corals from the Devonian period (some 360 million years ago) the number of fine growth bands within the annual increments approximated 400, while corals from the more recent Carboniferous period (some 320 million years ago) had a mean of 380. He interpreted these findings as implying that the number of days per annum had decreased progressively since the Devonian period. Probably the days had become longer because of slowing of the earth's rotation because of tidal friction. It would thus appear that some species of corals may be used as fossil clocks.

There is evidence that some species of coral appear to grow throughout life, while others may cease growing once they have reached a certain size. In 1890, William Saville-Kent measured three colonies at Thursday Island. The same colonies were subsequently measured by A. G. Mayer in 1913. A colony belonging to a species of *Symphyllia* had grown from 0.8 to 1.8 metres in diameter during this period, and a colony belonging to a species of *Porites* had grown from 5.8 to 6.9 metres in diameter. On the other hand, a colony belonging to a species of *Goniastrea*, which measured 2.4 metres in diameter in 1890, had the same diameter when measured in 1913.

Coral colonies are potentially long-lived; some may live for centuries. However, corals are subject to a number of destructive factors (see chapter 23), and some colonies may survive for only a few years. Also, growth of a coral colony could be retarded or checked completely by a number of factors, particularly by interactions with other species (competition and predation). Indeed, the initial rapid growth rate of a coral colony is frequently followed by a slowing down leading to an almost complete cessation of growth.

It is frequently stated that colour runs riot on a coral reef. Corals themselves contribute substantially to the colour displayed. Often corals adopt the hue of their contained zooxanthellae, which are usually some shade of yellow, brown, or green. However, pigment cells containing black, red, or orange granules may be present in the epidermis, and different combinations of these coloured granules give rise to a wide range of tints. Sometimes different specimens of the same species of coral show marked differences in colour.

The reproductive organs of coral polyps occur on the mesenteries in the coelenteron. In some species only eggs or sperm are produced by individual polyps at any one time. In other species (e.g., *Pocillopora brevicornis*), individual polyps have been found to possess ripe eggs and sperm at the same time; self-fertilization is possible in such cases. Also, it is possible that polyps change sex as they age. In most species it is not known whether fertilization (union of egg and sperm) is normally external or internal. In some cases larvae resulting from fertilization are brooded within the polyp.

Reproductive activity has been found to be continuous throughout the year in some species but seasonal in other species. Sometimes (e.g., in *Pocillopora bulbosa*) the rate of release of larvae is affected by the phases of the moon, an example of *lunar periodicity*. Mature colonies of some species of coral are known to release thousands of larvae (called *planulae*) at a time.

Larvae just released swim upwards towards the light. Subsequently, before attachment, they change their behaviour and swim away from light towards the sea-floor. Apparently most larvae attach within two days of release from the parent polyps. Many appear to settle near their parents. Sometimes the larvae are released at low water in packets coated with mucus which adheres to objects in the vicinity of the parent coral. However, the larvae of some species are capable of remaining for months in the surface waters, and these are of importance with respect to the distribution of the species.

Little is known about how the larvae choose a place to settle. The presence of numerous predatory organisms makes settling a hazardous process. In some cases the presence of coralline algae appears to be a prerequisite for successful settling. Mortality in early life, particularly at the planula stage and during the period after settling, is especially heavy.

Both physical and biological factors affect the distribution of corals. Physical factors such as water temperature, salinity, degree of sedimentation, extent of wave action, and water depth play a major role in determining the broad distributions of corals, as discussed in chapter 23. However, biological factors such as competition and predation play a major role in determining the fine-scale distribution of corals as discussed in chapters 14 and 15.

6

The Reef Builders — Algae

Apart from a few species of sea-grasses (phanerograms) which occur in patches on some coral reefs, algae are the dominant plant forms present. Their abundance on any reef appears to be inversely related to the abundance of living corals. Because of the efficient feeding methods employed by corals, algal spores (the reproductive bodies of many algae) cannot settle and grow on living corals. Also, most corals have efficient methods for acquiring and holding living space, which prevent encroachment by established algae. Consequently algae are, on the whole, restricted to regions of a reef that are unfavourable for coral settlement and growth. For example, some species of algae are able to withstand the pounding surf and wave surge on exposed reef fronts. Algae are rapid colonizers of space vacated by living corals; indeed, dead coral skeletons and semi-consolidated rubble provide excellent substrates for algae. As most algal species require exposure to adequate light for photosynthesis, most are found in exposed situations, and only a few algal species occur under coral boulders, under overhangs, and in caves on reefs.

Despite these restrictions on their distribution, which are in part responsible for the marked zoning patterns exhibited by algal species living on reefs, algae are abundantly represented. It has been estimated that about 330 species of algae occur on the Great Barrier Reef. While some species are tiny and inconspicuous, other species form large, fleshy structures. Indeed, coral-reef algae exhibit an amazing variety of form. Also, despite the drab appearance of some common species, algae display a wide range of colour. Colour was in fact used as a basis for classifying algae by early naturalists. The principal algal groups found on coral reefs are discussed below.

Green Algae (Division Chlorophyta)

The division Chlorophyta is a large group of algae which includes unicellular as well as multicellular forms and numerous freshwater as well as marine representatives. The algal body, or *thallus* as it is known technically, exhibits a great variety of shapes in the different species. Their green colour stems from the presence of large amounts of chlorophyll located in structures called *chromatophores*. The multicellular marine species often assume striking shapes. Some form a bright green felt-like mass (e.g., species of *Chlorodesmis*) or green spheres (e.g., species of *Valonia*), and others resemble bunches of green grapes (e.g., some species of *Caulerpa*). *Codium spongiosum* forms large, solid, irregularly lobed, dark green masses, while *Boodlea composita* forms a light green, maze-like meshwork. Some stalked forms resemble parasols (e.g., species of *Acetabularia*). Some species are encrusted with lime. Indeed, the disclike or beadlike segments of species of *Halimeda* contribute significantly to the reef sediments. Skeletons of living corals are often penetrated by species of the boring green alga *Ostreobium*.

Some of the genera represented: *Boodlea, Caulerpa, Halimeda, Acetabularia, Valonia, Dictyosphaeria, Enteromorpha, Codium, Bryopsis, Ostreobium, Chlorodesmis.*

Blue-Green Algae (Division Cyanophyta)

Blue-green algae either are unicellular or form segmented filaments that are regarded as multicellular since adjacent segments (cells) have common end walls. They reproduce by fission or by fragmentation of filaments. Sometimes they contain cellulose in their walls and in this respect differ from bacteria, which they resemble in many other respects. Some species form macroscopic clusters of filaments that are attached to the substratum. Often these appear as threadlike growths. They are rapid colonizers of the skeletons of recently killed corals. Although they exhibit a wide colour range, the predominant colour of cyanophytes is blue-green because of the presence of a pigment called phycocyanin. Blue-green algae are regarded as being among the oldest and most primitive life forms on this planet.

Some blue-green algae have become associated with fungi to form lichens, of which there are some marine representatives. Blue-green algae are responsible for producing some potent toxins. Some species (e.g., *Entophysalis* and *Mastigocoleus*) penetrate the skeletons of dead corals.

Some genera represented: *Microcoleus, Schizothrix, Entophysalis, Hormothamnion, Mastigocoleus.*

Brown Algae (Division Phaeophyta)

All members of the division Phaeophyta are multicellular and range in size from microscopic forms to the giant kelps that attain heights of 30 metres or more. Such giants are not, however, found on coral reefs, although some brown seaweeds (e.g., species of *Sargassum* and *Cystoseira*) are among the tallest of the algae found on reefs. The common name applied to the group — brown algae — is not entirely appropriate, as some species are olive green. Even so, most are brownish, owing their colour to a pigment called fucoxanthin. The thallus may be a simple filament or it may be a complex branching structure. Many species possess strap-like structures resembling leaves. Also, some (e.g., *Sargassum* species) have gas-filled bladders that buoy up the alga. A few species (e.g., species of *Padina* and *Lobophora*) are fan-shaped. In *Turbinaria ornata*, the branches of the thallus resemble small trumpets with serrated margins. On some reefs the large, gas-filled sacs of *Colpomenia sinuosa* are prominent. Another two brown algae that are usually well represented on reefs are *Chnoospora implexa*, which forms a large spongy meshwork, and *Hydroclathrus clathratus*, whose strap-like thallus carries numerous large perforations and is aptly termed the wire-netting alga.

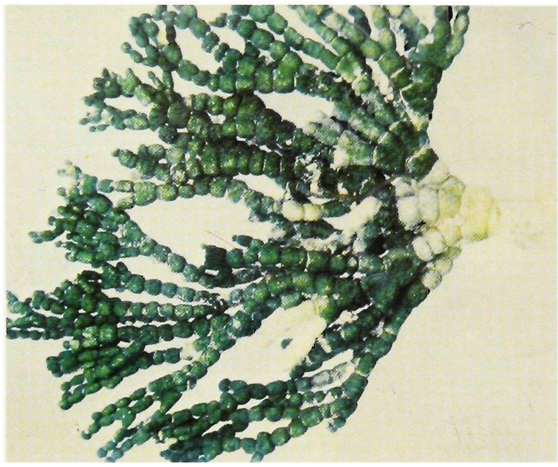
Some genera represented: *Padina, Cystoseira, Sargassum, Lobophora, Hydroclathrus, Turbinaria, Chnoospora, Colpomenia.*

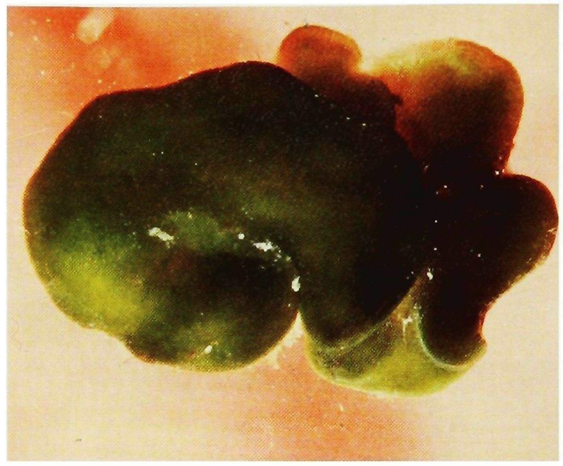
Red Algae (Division Rhodophyta)

Many small to medium-sized seaweeds belong to the division Rhodophyta, most of which are multicellular and attached to the substratum. Most have elaborate thalli, which may be cylindrical, branched, flattened, foliaceous, or disc-shaped. The red colour, for which the group as a whole is noted in temperate waters, stems from the presence of a red pigment called phycoerythrin. However, many red algae occurring on the Great Barrier Reef are dark, sometimes blackish, because of the presence of other pigments, particularly phycocyanin. Perhaps it would cause less confusion if they were referred to as rhodophytes rather than red algae. Rhodophytes differ from other algae in their lack of motile sperm. Sperm must be carried to the eggs by water currents if fertilization is to occur.

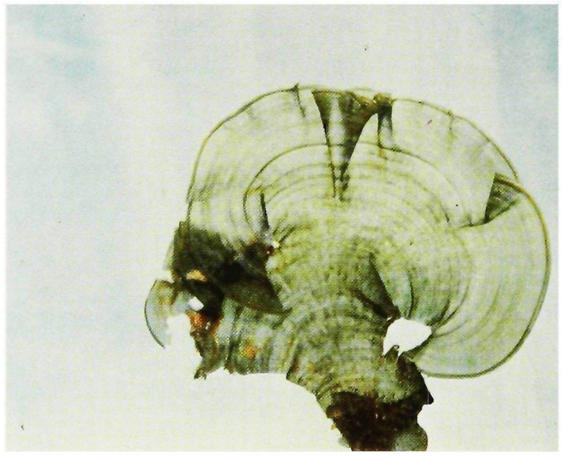
In Great Barrier Reef waters, rhodophytes tend to be less conspicuous and to constitute a lower proportion of the total flora present than they do in temperate waters. Nevertheless, they are still well represented. Some species are short and form a fur-like covering on coral

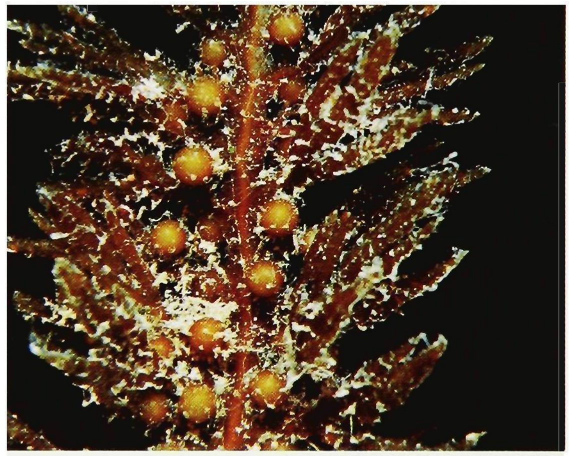

37


38


39


40

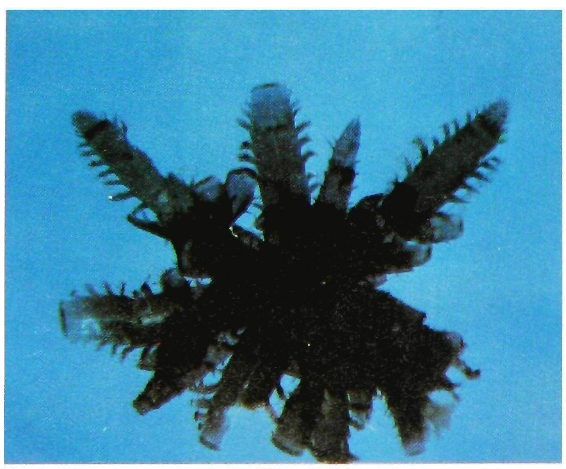

41


42


43


44


45


46


47


48

rubble. Others (e.g., species of *Laurencia*) form fleshy branching structures. *Gelidiella acerosa* has a comb-like structure.

The cell walls of some rhodophytes have a coating of lime. Some form multi-branched clusters (e.g., species of *Amphiroa* and *Lithophyllum*). Others have a more encrusting habit (species of *Peyssonellia, Porolithon* and *Lithothamnion*); these are the so-called coralline algae, which play a major role in the consolidation of reef debris and in the stabilization of exposed regions of reefs.

Some genera represented: *Amphiroa, Gelidiella, Laurencia, Polysiphonia, Hypnea, Centroceras, Champia, Jania, Chondria, Lithophyllum, Lithothamnion, Porolithon, Corallina, Galaxaura, Amansia, Peyssonellia.*

Diatoms (Division Chrysophyta)

The photosynthetic structures possessed by members of the division Chrysophyta contain xanthophylls and carotenes and have yellow-green to yellow-brown colours. Diatoms are the most abundant marine representatives of this group of algae. Indeed, they are the most abundant component of marine plankton (see p. 000). They are unicellular or colonial organisms, each individual possessing glassy walls containing silica. The walls, which exhibit a great variety of shape and ornamentation, always consist of two halves that fit together like a box with its lid. Although essentially planktonic organisms, many occur on the surfaces of coral reef sediments.

Dinoflagellates (Division Pyrrhophyta)

Dinoflagellates are small unicellular algae characterized in free-living forms by the possession of two whip-like appendages, or *flagella*, of unequal length. The cell wall, when present, is composed largely of cellulose. Many species are found in marine plankton, some (e.g., species of *Noctiluca*) causing phosphorescence of the sea, others sometimes being present in such numbers as to colour the sea.

Some dinoflagellates live in an encysted state in the tissue of various animals, particularly corals, where they are known as zooxanthellae. Despite the presence of a cyst wall (periplast), the photosynthetic abilities of the encysted algae appear to be as great as in free-living motile forms.

Facing page
Illustration 37
The green alga, *Caulerpa racemosa.*

Illustration 38
The green alga, *Halimeda cylindrica.*

Illustration 39
The green alga, *Codium spongiosum.*

Illustration 40
The green alga, *Chlorodesmis fastigiata,* commonly known as turtle weed.

Illustration 41
The brown alga, *Padina gymnospora.*

Illustration 42
A brown alga, *Sargassum* sp.

Illustration 43
The brown alga, *Chnoospora implexa.*

Illustration 44
The brown alga, *Turbinaria ornata.*

Illustration 45
The blue-green alga, *Hormothamnion enteromorphoides.*

Illustration 46
The red alga, *Amansia glomerata.*

Illustration 47
The red alga, *Galaxaura* sp.

Illustration 48
The red alga, *Peyssonellia inamoena.*

Roles of Algae

Fixation of light energy by the process of photosynthesis is one of the fundamental roles played by coral reef algae and is discussed in chapter 15. While macroscopic algae are of great importance here, the part played by microscopic algae, particularly diatoms, as a source of energy and nutrients for other organisms in the coral reef community is considerable and should not be overlooked. Neither should the part played by algae that live in the tissues of animals. Their role in energy and nutrient provision in corals and in the calcification of corals has already been discussed.

Some algae elaborate powerful toxins, some of which are in the nature of antibiotics that are used in the holding or acquisition of living space. Others are in the nature of poisons. If ingested, they may cause serious injury or even death. However, some predators have evolved mechanisms for dealing with these toxins and even for converting them to their own use.

Some of the boring algae, such as species of *Ostreobium*, penetrate the skeletons of corals, weakening them and making them susceptible to the attacks of herbivorous parrot-fish.

Calcareous algae, whose remains dominate reef sediments, play major roles in reef construction (see chapter 7). Some types of calcareous algae also exert a stabilizing action on exposed windward sides of many reefs, enabling the windward side of a reef to act as a breakwater which in turn permits some reef growth to occur on the lee side. Calcareous algae tend to form a casing around the basal regions of corals, particularly branching corals. It is thought that this casing gives added strength to coral skeletons and helps to protect them from physical erosion and from the activities of boring organisms.

7

Reef Construction

While the commonly held view that corals provide the bricks and calcareous algae provide the mortar in reef construction is a simplistic one, there is ample evidence that calcareous algae stabilize the framework provided by corals, particularly when the upward growth of this framework reaches the zone where wave action becomes pronounced. Indeed, in the regions of a reef that are frequently exposed to pounding surf and wave surge, calcareous algae are the dominant organisms present. Their skeletons, which are composed of calcite (a crystalline form of calcium carbonate) appear to be harder and certainly less soluble than the aragonite (another crystalline form of calcium carbonate) of which the skeletons of corals are comprised. On exposed regions of the windward sides of reefs, calcareous algae form a smooth, hard surface to the reef front which provides an effective barrier to erosive forces.

Unfortunately, there is little information on the growth rates of calcareous algae, and the actual extent to which they contribute to the bulk of a reef at their site of growth is in dispute. Estimates of net calcification rates on both windward and leeward sides of reefs give values of about 4 kilograms per square metre per year. However, most if not all of the calcareous material produced each year on the windward side is removed as a result of the action of erosive agents linked with water movements. It would seem likely that outward growth on the windward side of a reef, if it occurs at all, is very slow and that the reef front is essentially static with constructional and erosive forces in equilibrium. However, this part of the reef acts as a breakwater, permitting reef construction to proceed on the lee side of the reef. Here corals can proliferate and calcareous sediments can accumulate to some extent.

Calcareous structures — which may be the walls of calcareous algae; the skeletons of corals or forams, or bryozoans, or sea-fans; the calcareous tubes of some worms; the shells of molluscs; the skeletons of barnacles and sea-urchins; or the skeletal spicules of soft corals, holothurians, and other organisms exposed when these organisms die — are all broken down to some extent by the actions of various physical and biological agencies (see chapter 23) to produce sediments. Among the principal destructive agencies operating on reefs are gales and the tropical storms known as cyclones. The mechanical force exerted by the waves and pounding surf generated by such disturb-

Facing page, above
Small colourful colonies of acroporid corals near the reef crest at Heron Island.

Facing page, below
Micro-atolls of species belonging to the genus *Porites,* on the reef flat at Low Isles. Black sea-urchins, *Diadema setosum,* are in evidence.

Below
The seaward slopes of Masthead Island showing the spur and groove system on the reef slope.

ances is sufficient to smash the skeletons of numerous shallow-water corals and to cause mass mortalities of associated organisms. Loose fragments of calcareous structures occurring in shallow water are abraded by being rolled about on reefs by wave action and tidal currents, and small particles are broken from them.

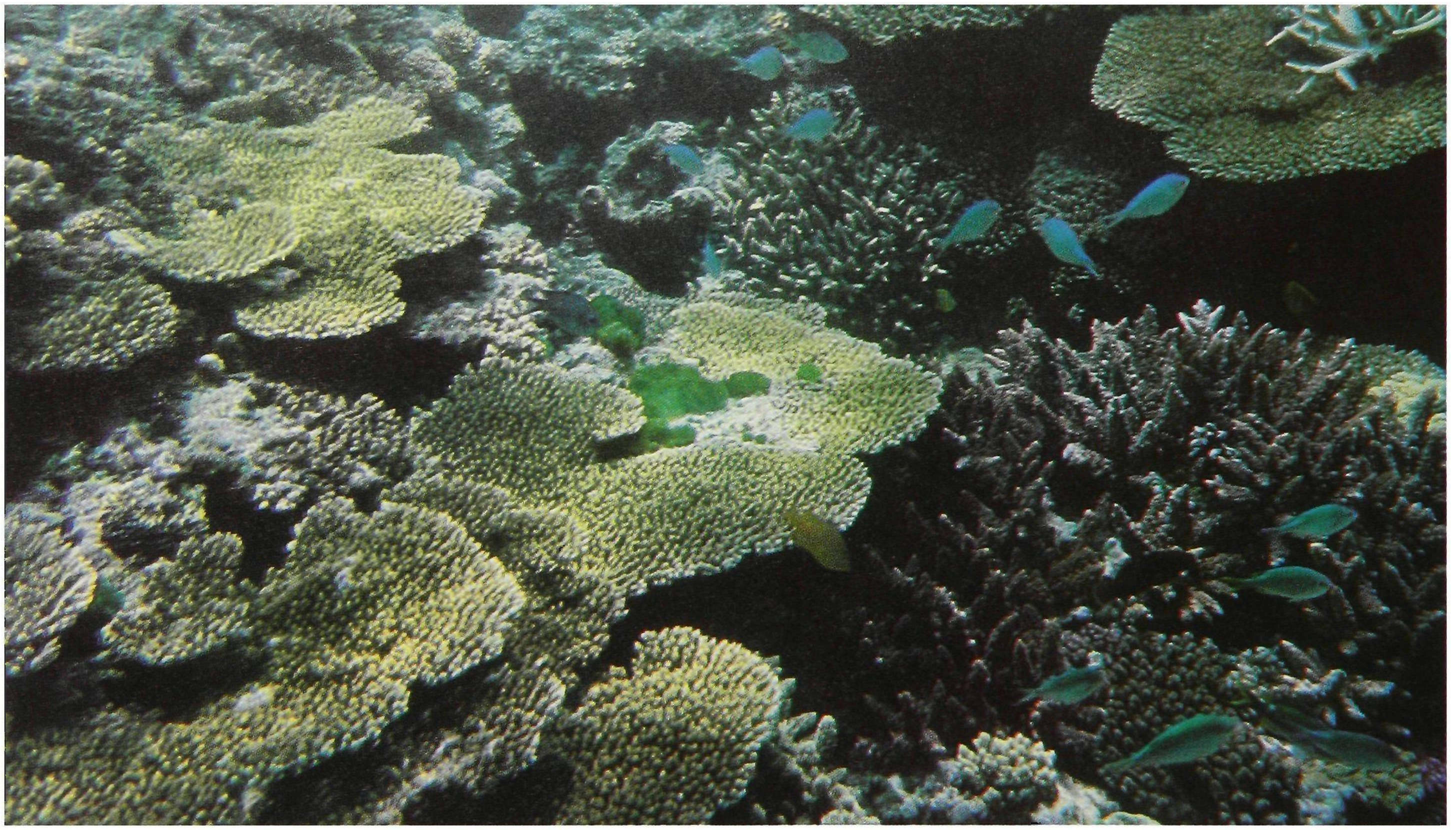
Some fishes are important agents in the production of calcareous sediments. Parrot-fish (scarids) have strong beaks which they use in abrading the skeletons of dead corals in order to obtain boring algae. They also abrade the surfaces of dead coral skeletons incidentally when grazing the algal turf growing on these skeletons. Some large wrasses (labrids) have been observed to bite off short pieces of branching corals, possibly in attempts to obtain invertebrates associated with the corals. Surgeon-fish (acanthurids) are the major eaters of coralline algae. Particles of calcareous material are not digested and pass right through the alimentary tracts of the fish. It has been estimated that reef fishes are responsible for depositing between 2,000 and 3,000 kilograms of calcareous material per hectare of reef per year. In addition, there are many organisms, including various worms, molluscs, and barnacles, that bore into calcareous skeletal materials, abrading particles in the process and thereby contributing to sediment production. Eventually fine calcareous particles are produced, giving rise to the so-called coral sand that covers large areas of some reefs.

Of course, calcareous sediments usually do not remain at the site of production. Apart from water movements, which are powerful agents for shifting sediments, all sediment-feeding animals of coral reefs are active in changing the position of surface sediments. On most coral reefs, holothurians are probably the most important sand deposit feeders. One common species, *Holothuria atra*, passes about 44 grams of sediment per day through its alimentary canal.

As the winds in the Great Barrier Reef area blow predominantly from the south-east, water movements across the reefs are mostly to the north-west. Actual measurements of water movements across reefs during rising tides and ten-knot south-easterly winds show water velocities of 25 to 50 centimetres per second — sufficient to move fine sediment. At times, winds are much stronger and the water movements across reefs generated show greater velocities and are capable of moving coarse sediments. (During cyclone disturbances, even huge coral boulders may be moved.) The sediments moved across reefs may accumulate in shallow water on the lee side of reefs. Alternatively they may be swept away from reefs and accumulate in deeper water. Their fate is determined by the interplay of water currents, water depths on the lee side of reefs, and the availability of sediment traps. These traps are formed by fragments of coral skeletons, skeletons of forams, and the calcareous discs of algae such as those of *Halimeda* being bound by coralline algae so as to form a semi-consolidated meshwork. The meshwork is usually caught up in the bases of corals, particularly branching corals, growing on the lee of a reef. Fine sediment is trapped in the meshwork and may fill the interstices of the meshwork. This process of accumulation and consolidation of calcareous material continues, and at an accumulation depth of about 5 metres the consolidated material is converted to reef limestone.

Reef construction as described cannot, of course, proceed above mean low water. This leads to the formation of a reef flat in the lee of the breakwater formed by the stabilized windward edge of a reef. In effect, once reefs grow up to the water surface, they grow downwind, as noted by P. J. Davies. However, the capacity for reef growth on the lee side appears to be limited and in many cases may have reached a state of equilibrium with destructive forces. On most reefs of the Great Barrier Reef the reef flat near the windward edge of the reef ranges from 100 to 400 metres in width. The present platform reefs of the Great Barrier Reef have grown on top of antecedent knoll-like structures, and these underlying structures strongly influence the shapes and sizes of the reefs. Many such reefs show downwind projections called cusps. Sometimes the area of shallow water substrate available for coral growth has been sufficient to enable these cusps to grow together and form a lagoon, thereby giving rise to the atoll-like platform reefs of the Great Barrier Reef. In other cases the presence of depressions on the surfaces of the antecedent knoll-like structures might have led directly to lagoon formation. The degree of infilling of each lagoon depends, among other factors, on the length of time the associated reef has been at the surface and subject to wave action. The shapes of reefs are also influenced by hydrodynamic conditions such as strength and direction of currents, tidal range, extent of wave action and by proximity of other reefs.

As discussed in chapter 3, the present reefs of the Great Barrier Reef have had a long and complex history. Their basements were constructed of limestone thousands of years ago, before the Pleistocene lowerings of sea-level exposed them to sub-aereal erosion. During these sea-level lowerings, their surfaces were sculptured by erosive forces. Then, as the seas finally returned some ten thousand years ago, the eroded reef cores were covered with water and provided solid substrates for the development of new coral reef communities. These reef communities grew vertically as the waters rose. The numbers, positions, shapes, and sizes of the new reefs were governed by the numbers, positions, shapes, and sizes of the old erosion surfaces from which the new reefs grew. Because the surfaces were often at different depths, the vertically growing reefs reached present sea-level at different times over the last six thousand years. Possibly a few "deep reefs" such as North-west Reef near Cairns are still



growing vertically towards the water surface, but the great majority reached the surface hundreds of years ago. When they neared sea-level they came under the influence of waves and currents which have further modified their shapes. Such a history accounts well for the numbers, present distribution, and variable appearance of the reefs.

It is not known whether overall reef growth in the Great Barrier Reef area before the arrival of Europeans was in a state of balance with destructive agencies. Probably it was. Certainly the structure of the existing reefs, the topography of the sea-floor among the reefs, and prevailing hydrographic conditions in the area would appear to preclude any marked increase in the numbers or sizes of the reefs in the immediate future.

Facing page, above
Tabular and branching species of *Acropora* in a drainage channel on the upper part of the reef slope at Tryon Island reef.

Facing page, below
A forest of branching *Acropora* species on the lee side of Tryon Island reef.

Above
Pools and drainage channels near the reef crest, Heron Island at low tide.

8

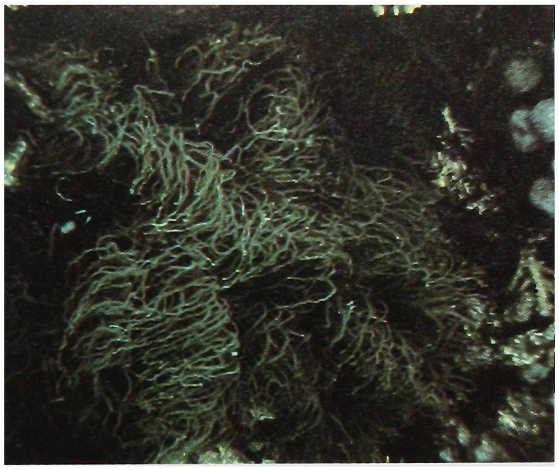
Other Attached Animals on the Reefs

As well as hard corals, numerous other animals are attached to the semi-consolidated rubble of the reef surface. Some of these — the tube-forming worms, the barnacles, and the bivalved molluscs — will be dealt with in subsequent chapters. Others are discussed below. Most of these animals are colonial, and many, like the hard corals, are cnidarians (Phylum Cnidaria).

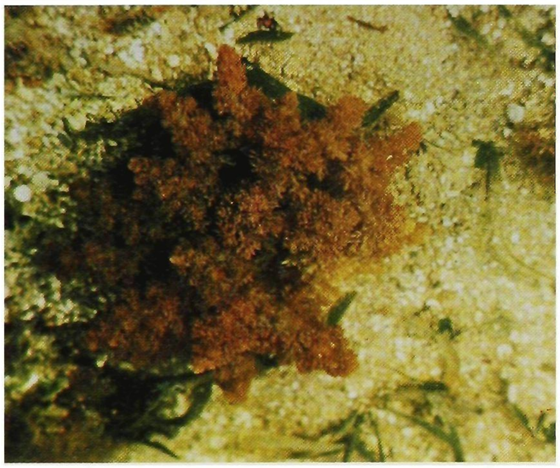
Sea Anemones (Class Zoantharia, Order Actiniaria)

Anemones are cnidarians that resemble enlarged coral polyps with thick, muscular body walls. They occur usually as separate individuals lacking hard skeletal material. Tentacles, which may be pointed or bead-like, occur in rings around the mouth or cover the whole of the surface where the mouth occurs. The end opposite the mouth usually forms a sucker-like disc for temporary attachment to a solid object but is adapted for burrowing in some species. Injector type nematocysts (stinging capsules) on the tentacles are used to paralyse prey. In addition, another type of nematocyst, called a spirocyst, is present. When the coiled spirocyst thread discharges, it liberates an adhesive material from the tip of the thread. This adhesive material entangles and helps to inactivate prey and to bind it to the tentacles. Sometimes relatively large prey, including crustaceans and small fish, are caught. Some species of anemone appear to rely more on minute organisms and organic detritus as a food source than on sizeable prey, and these anemones employ ciliary-mucoid feeding methods similar to those employed by some species of coral. In some species of anemone the

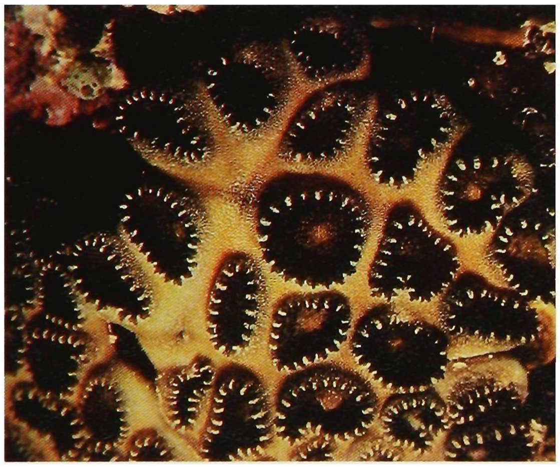
Facing page
Part of a colony of a sea-fan belonging to the genus *Melithaea*.


56

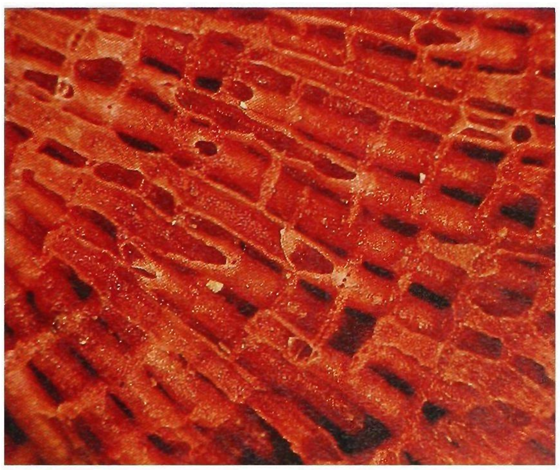
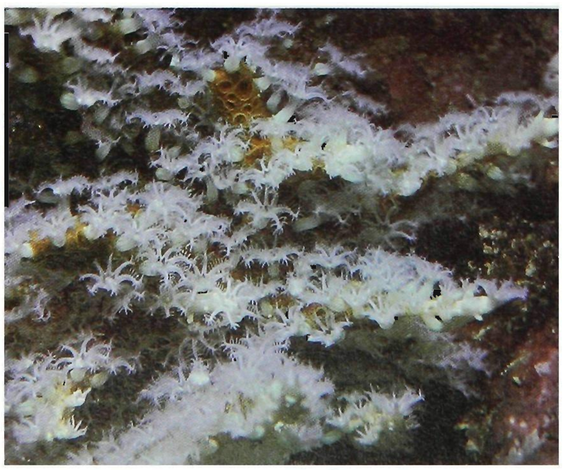
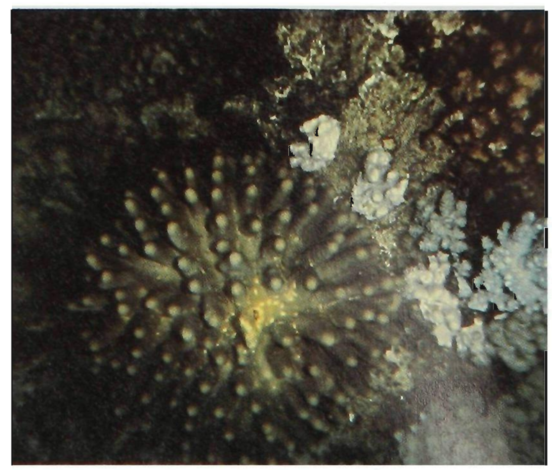
57

58

59

60

61

62

63

64

65

66

67

sexes are separate; representatives of other species may be hermaphrodites. Asexual reproduction by fission or by budding from the basal disc occurs commonly in some species.

Numerous species of anemone representing several families occur in Great Barrier Reef waters. They are found in crevices, in rubble among living corals, on and under boulders, and burrowing in the sand on reef flats, reef slopes, and in the deeper waters on the edges of reefs. As is the case with many animal groups encountered on the Great Barrier Reef, few of the species of anemones found there have been identified. Some species show a great range of colour forms. While some species are small (only a few millimetres in diameter) others, such as *Stoichactis kenti*, may be up to 1 metre in diameter. A few, such as the fire anemone, *Actinodendron plumosum*, which is common on some fringing reefs, are capable of inflicting severe stings on humans.

Some of the genera represented: *Actinodendron, Paractis, Stoichactis, Radianthus, Cryptodendron, Calliactis.*

Zoanthids (Order Zoanthiniaria)

Most zoanthids are colonial forms resembling clusters of small anemones linked together and attached to the substratum by ramifying tubular structures called *stolons*. No skeleton is present. The individual polyps carry unbranched tentacles numbering six or, more usually, multiples of six. Paired partitions subdivide the body cavity of each polyp. Zoanthids occur in crevices on reef crests and are sometimes found on coral boulders. Occasionally they form large carpets on reef crests. They are noteworthy because individual polyps change sex as they age. Some polyps contain a powerful toxin.

Genera represented: *Palythoa, Epizoanthus.*

Cerianthids (Class Ceriantipatharia, Order Ceriantharia)

Cerianthids occur as single individuals each encased in a mucous tube (impregnated with detritus) that is buried vertically in the substratum. Each individual resembles an elongated anemone that possesses two rings of tentacles, those of the inner ring being shorter than those of the outer ring. Cerianthids are found among sand in back-reef areas and in the deeper water on the periphery of platform reefs in Great Barrier Reef waters. They are common in sandy areas of some fringing reefs but have been little studied.

Genus represented: *Cerianthus.*

Facing page

Illustration 56
The tentacles of a large reef anemone belonging to the genus *Physobrachia.*

Illustration 57
A colourful reef anemone.

Illustration 58
Some of the tentacles of an anemone, *Stoichactis kenti.*

Illustration 59
The stinging anemone, *Actinodendron plumosum.*

Illustration 60
A colony of anemones belonging to the family Hormathiidae.

Illustration 61
Colonies of the zoanthid, *Palythoa caespitosa.*

Illustration 62
The open mouths of zooids belonging to a species of the zoanthid *Palythoa.*

Illustration 63
Part of a whiplike colony of a species of black coral belonging to the genus *Cirrhipathes.*

Illustration 64
Expanded polyps of a colony of a clavulariid belonging to the genus *Clavularia.*

Illustration 65
The red skeleton of the organ-pipe coral, *Tubipora musica.*

Illustration 66
A telestacean, *Telesto* sp.

Illustration 67
The soft coral, *Lobophyton pauciflorum*, at Green Island.

Facing page
Illustration 68
Colonies of the soft coral *Sarcophyton trocheliophorum* on the reef flat at Low Isles.

Illustration 69
The expanded polyps of the soft coral, *Sarcophyton trocheliophorum.*

Illustration 70
Part of a colony of a soft coral, *Dendronephthya* sp.

Illustration 71
Part of the colony of a soft coral belonging to the family Siphonogorgiidae.

Illustration 72
Colonies of the xeniid, *Anthelia glauca.*

Illustration 73
Expanded polyps of a sea-pen belonging to the family Veretillidae.

Illustration 74
Part of a colony of a sea-fan, *Suberogorgia* sp.

Illustration 75
Part of a colony of an unidentified sea-fan.

Illustration 76
A sea-whip, *Juncella* sp.

Illustration 77
The hydroid, *Aglaeophenia cupressina.*

Illustration 78
The hydroid, *Halocordyle disticha.*

Illustration 79
A colony of the hydrozoan *Stylaster*

Black Corals (Order Antipatharia)

Black corals form shrublike or whiplike colonies ranging from a few centimetres to over a metre in height. They are attached to the substratum by the main trunk. Individual polyps are small and resemble those of true corals, although their tentacles cannot be retracted. However, instead of a rigid calcareous skeleton, black corals possess a flexible skeleton of black or dark brown horny material. This will take a glossy polish and is used in the manufacture of so-called black coral jewellery. Black corals are found on reef slopes and in the deeper water on the edge of reefs in the Great Barrier Reef region. They appear to be more common in the waters off fringing reefs of some mainland islands than in the waters near platform reefs.

Genera represented: *Antipathes, Cirrhipathes.*

Stoloniferans (Class Alcyonaria, Order Stolonifera)

Stoloniferans form small colonies. Individual polyps each have eight feathery tentacles and arise from ramifying tubular stolons. Clavulariids and organ-pipe coral are stoloniferans.

Clavulariids (Clavulariidae). Large polyps, about 2 centimetres high, arise separately from ramifying root-like stolons in members of the family Clavulariidae. Each polyp has eight feathery tentacles. Calcareous spicules are present. Clavulariids are found in the deeper water around reefs, particularly on the bases of coral pinnacles found in back-reef areas.

Genus represented: *Clavularia.*

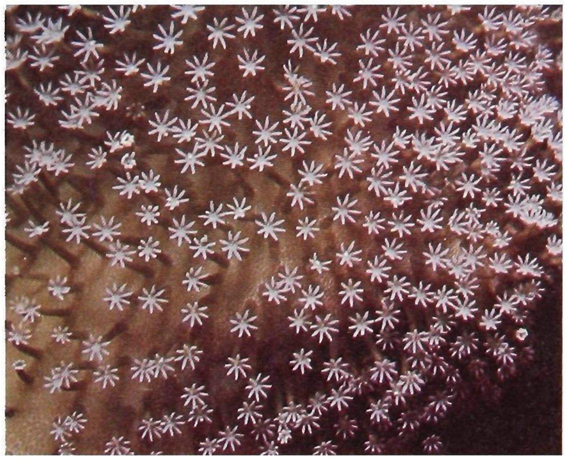
Organ-pipe coral (Tubiporidae). In the aptly named organ-pipe coral, individual polyps are accommodated in parallel calcareous tubes that are connected at intervals by calcareous shelves running at right angles to the tubes. The tubes are red and retain their colour when the large, greenish polyps die. Organ-pipe coral forms small colonies that are commonly encountered on reef flats of platform reefs.

Genus represented: *Tubipora.*

Telestaceans (Order Telestacea)

Colonies of telestaceans are formed as a result of elongate polyps growing up as stems from a root-like base. Numerous short lateral

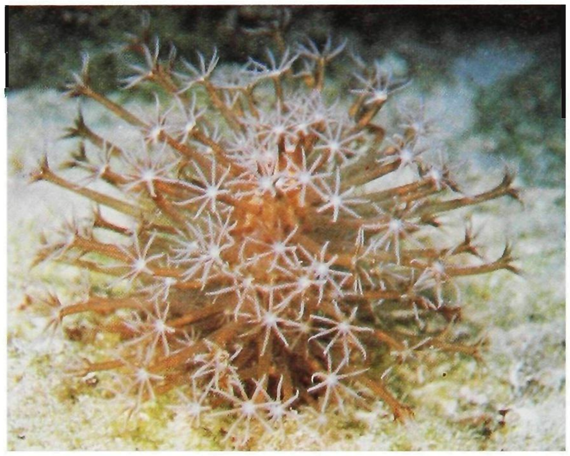

68


69

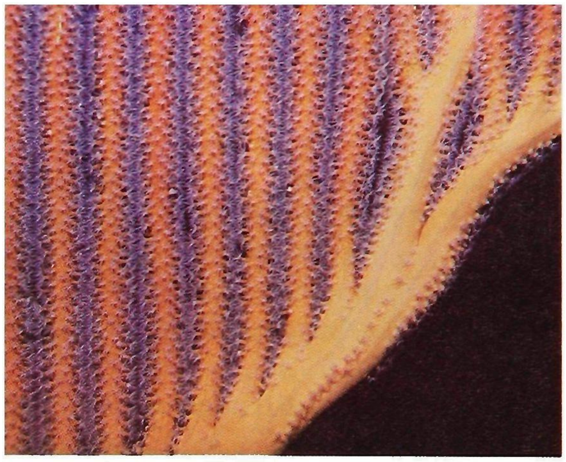

70

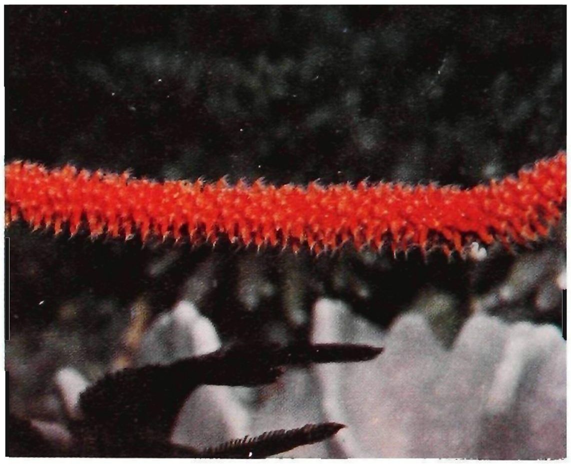

71


72

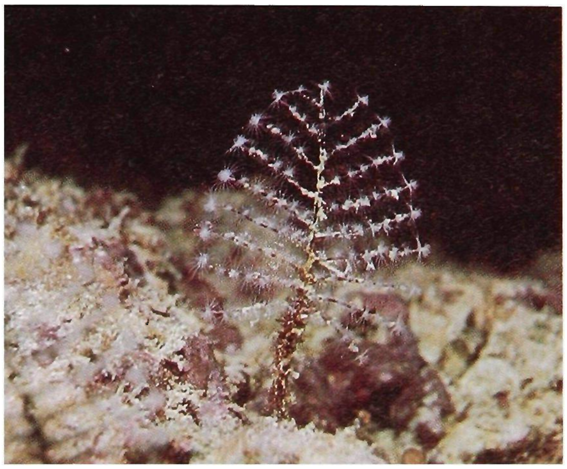

73

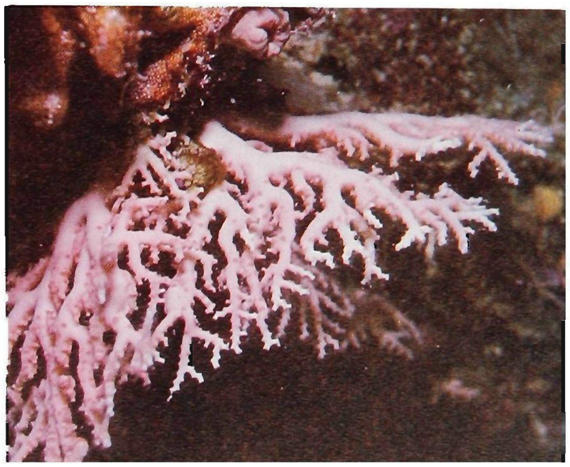

74


75


76


77


78


79

polyps protrude from each stem. Each polyp has eight featherlike tentacles. Spicules are present in the body walls of the polyps. Frequently sponges become associated with the stems. Telestaceans are found in lagoons and in the deeper water around the edges of reefs. Only one family (Telestidae) of telestaceans appears to be represented in Great Barrier Reef waters.

Genus represented: *Telesto.*

Soft Corals (Order Alcyonacea)

Soft corals consist of colonies of polyps interconnected by canals which permeate a gelatinous matrix in which calcareous spicules are found. Each polyp has eight featherlike tentacles and can be withdrawn into the matrix. Soft corals are common on reef flats and back-reef areas of some reefs. They grow completely exposed, no doubt because of the need to expose the zooxanthellae present in their tissues to light. Soft corals will grow in situations subject to considerable wave action, although they may be excluded from such situations normally by hard corals. If hard corals are killed by natural disasters or by infestations of the crown-of-thorns starfish, *Acanthaster planci,* their dead skeletons are often covered by carpets of rapidly growing soft corals. At least four families of soft coral occur in Great Barrier Reef waters. These are alcyoniids, nephtheids, siphonogorgiids, and xeniids.

Alcyoniids (Alcyoniidae) form large, fleshy colonies. Frequently they are vase-shaped, often lobed, and sometimes branching. The elongate polyps are connected by a system of large and small canals and are embedded in a thick and tough coenchyme which bears numerous spicules. The basal stem of the colony is devoid of polyps. Alcyoniids are abundant on many reefs of the Great Barrier Reef, particularly on reef flats in the northern sector. Greens, yellows, and browns are the dominant colours. Some colonies are 1 metre across, and frequently the polyps expand during daylight hours.

Genera represented: *Sarcophyton, Lobophyton, Sinularia, Cladiella.*

Nephtheids (Nephtheidae) form branching tree-like colonies; the polyps are borne on the ends of the branches. They have non-retractile tentacles, and each has a long gastral cavity that ends blindly in the coenchyme. Only a few polyps are interconnected. Long spicules visible to the unaided eye project beyond the polyps, forming a spiny defence. Frequently the polyps are pink or brown, with the thick

trunk and branches of the colony much paler. Nephtheids are found commonly in lagoons and in the deeper water around reefs.
Genera represented: *Dendronephthya, Litophyton.*

Siphonogorgiids (Siphonogorgiidae) bear a marked resemblance to gorgonians (i.e., sea-fans and sea-whips; see below), the colonies being erect, branching, and generally fan-shaped. A core of large spicules is present in the larger stems. Siphonogorgiids occur in lagoons and in the deeper water around reefs.
Genus represented: *Cactogorgia.*

Xeniids (Xeniidae) usually occur as small colonies about 12 centimetres in diameter. Each colony comprises masses of large, cylindrical polyps which are non-retractile. The polyps arise from a relatively small mass of coenchyme. A system of canals in the coenchyme unites individual polyps. Spicules, when present, occur as minute spherical or ovoid bodies. Only a single pair of partitions is present in the body cavity of each polyp. Although the large tentacles open and close at intervals, xeniids appear to rely solely on their contained zooxanthellae for their nutritive requirements. Xeniids are usually bluish, greyish, or brownish and are common on reef flats in the Great Barrier Reef area.
Genera represented: *Xenia, Heteroxenia, Anthelia.*

Blue Coral (Order Coenothecalia)

In the blue corals the skeleton is massive and indigo blue in colour when freshly broken but tends to be greyish-blue normally. It is perforated by canals that interconnect the polyps, each of which has eight featherlike tentacles and eight partitions in its body cavity as in polyps of most families of soft corals. Blue coral is common in the northern part of the Great Barrier Reef. The order Coenothecalia contains only one family (Helioporidae) and one genus.
Genus represented: *Heliopora.*

Sea-Pens (Order Pennatulacea)

Sea-pens are colonies consisting of a large, highly modified central polyp which either gives off short polyps from its surface or gives origin to parallel side branches from which short polyps arise. The polyps each have eight featherlike tentacles. The expanded end of the central polyp anchors it in soft substrates. Calcareous spicules are

Facing page
Illustration 80
A blue calcareous bryozoan belonging to the Order Cyclostomata.

Illustration 81
A bryozoan, often known as lace coral.

Illustration 82
Another lace coral, the bryozoan, *Reteporella graeffei.*

Illustration 83
An unidentified orange bryozoan encrusting the undersurface of a coral boulder.

Illustration 84
The brachiopod, *Frenulina sanguinolenta.*

Illustration 85
A colony of vase-shaped sponges belonging to the genus *Haliclona.*

Illustration 86
A brown sponge belonging to the genus *Pericharax.*

Illustration 87
An encrusting sponge.

Illustration 88
An orange sponge.

Illustration 89
A colony of sponges.

Illustration 90
A hemispherical sponge.

Illustration 91
An encrusting sponge.

present. In some species the whole colony can retract below the surface of the sea-floor. Sea-pens, which range from a few centimetres to over a metre in length, are found in soft sediments associated with some reefs, particularly fringing reefs. Possibly several families are represented, but the Australian sea-pens are poorly known.

Genera represented: *Cavernularia, Pennatula.*

Sea-Fans and Sea-Whips (Order Gorgonacea)

The polyps and connecting tissues of members of the order Gorgonacea produce a skeleton which may be calcareous or composed of a horny material called gorgonin. The skeleton takes the form of an axial rod from which side branches bearing the polyps arise. In many species (the sea-fans) the side branches are extensive and in some cases interconnect. In others (the sea-whips) the side branches are minute. Colonies are firmly anchored to the substratum by one end of the axial rod. Individual polyps are small and closely resemble those of soft corals in structure. Many sea-fans and sea-whips are found commonly on reef slopes and in the deeper water around the bases of reefs, but members of the families Isididae and Plexauridae occur commonly on reef flats. Unfortunately, the sea-fans of the Great Barrier Reef area are poorly known, although several families appear to be represented. While some species show a great range of colour, yellows, browns, and reds predominate. Other organisms such as sponges and feather-stars frequently associate with gorgonians, as sea-fans and sea-whips are also known.

Some genera represented: *Subergorgia, Mopsella, Paramuricea, Primnoella, Isis, Melithaea, Juncella, Rumphella.*

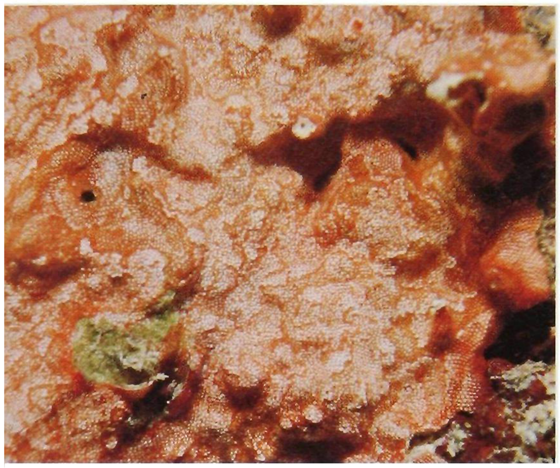
Hydrozoans (Class Hydrozoa)

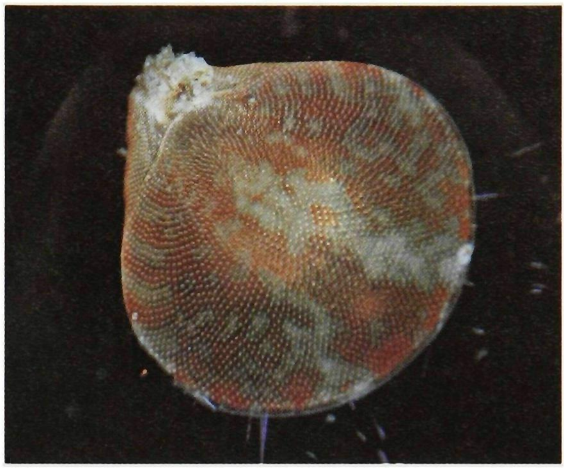
Among animals that possess nematocysts (the cnidarians) two basic forms occur. One is the polyp, which is a cylindrical animal with a mouth surrounded by tentacles at one end and a region modified for attachment at the other — the basic body form of anemones and individuals within a coral colony. The other basic body form is the medusa, which is bell-shaped or saucer-shaped and normally is not attached. This basic body form is possessed by the familiar jellyfish. There is a group of animals, the hydrozoans, that usually possess both polyp and medusa forms in their life history. Typically, these animals occur on reefs as fixed colonies of interconnected polyps. An outer


80

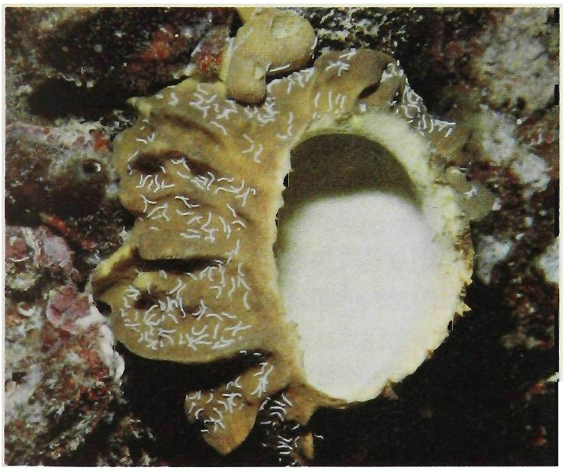

81


82


83


84

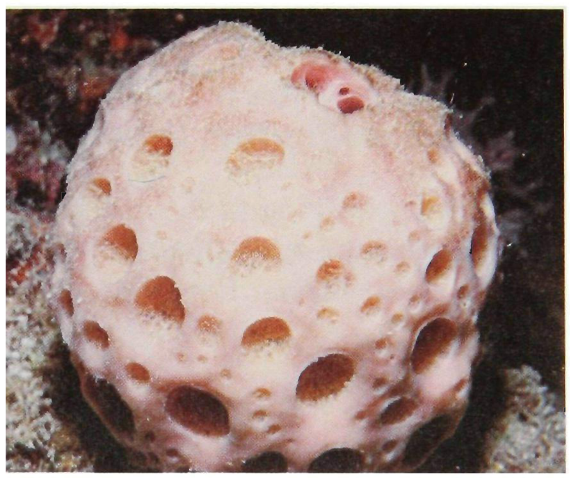

85


86


87


88


89


90


91

layer of tough, horny material usually invests the colony. In some species the polyps themselves lack a protective sheath of this horny material. In two families (Milleporidae and Stylasteridae) a calcareous skeleton is elaborated. The medusa form in hydrozoans is usually small and free-swimming and carries the reproductive organs. Larvae are produced from fertilized eggs, and these give rise to new polyps. Asexual reproduction is, of course, involved in colony formation.

Most attached hydrozoans are known as hydroids. Many of these form erect colonies, some of which are only a few millimetres in height, others of which are over 20 centimetres in height. The stinging hydroids, *Aglaeophenia cupressina* and *Lytocarpus philippinus*, have powerful batteries of nematocysts and can cause injury to humans (see chapter 19). Hydroids are commonly encountered growing on rubble or semi-consolidated debris on reef flats or under overhangs and in caves on reefs. As yet, not a great deal is known about the species occurring there.

Stylasterids (Stylasteridae) form small branching colonies in shaded situations on reefs, especially in caves and on the under-surfaces of overhangs on the edges of reefs. These hydrozoans are characterized by the presence in the calcareous skeleton of minute pores where the polyps are housed. They are usually brightly coloured, orange, blue, mauve, or pink being the colours commonly encountered. Stylasterids are common in their preferred habitat on the Great Barrier Reef.

Genera represented: *Stylaster, Distichopora.*

Fire corals (Milleporidae). In members of the hydrozoan family Milleporidae the interconnected polyps are embedded in a massive calcareous skeleton which may be erect and branching or flat and encrusting with lobes and buttresses. The colonies may be quite large and cover several square metres. They are typically of a yellow-brown colour and are readily recognized by the minute pores that accommodate the polyps. A tingling or burning sensation is usually perceived if one brushes against fire corals, and sometimes a rash appears on the skin at the point of contact with the coral. Fire corals are common on the Great Barrier Reef, particularly in drainage channels near reef crests.

Genus represented: *Millepora.*

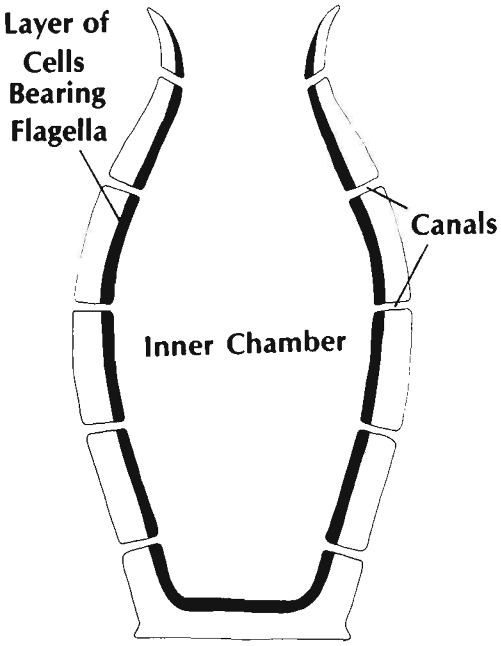
Bryozoans (Phylum Bryozoa)

Until recent times there was a general belief that the bryozoan fauna of the Great Barrier Reef was sparse, since relatively few species had been recorded from coral reefs in the area. However, it is now known that the bryozoan fauna of these reefs is rich and diverse. Bryozoans are colonial animals, the colonies of different species showing a wide range of form and size. Some are plantlike, some form encrusting sheets or erect plates or gelatinous lobes, and some — the so-called "lace corals" — resemble small corals. This variation in form is reflected in the variety of materials used to construct the colonies, for some of the colonies are calcified or partially calcified, and others are constructed of a cuticular or a gelatinous material.

Individuals of a colony are called *zooids*. They are very small, millions of them being found in some colonies. Each zooid is usually urn-shaped but may be specialized for one of several functions. Most are involved with feeding, and these are characterized by the possession of a structure called a *lophophore*, which has a cluster of ciliated tentacles. The mouth is situated at the base of the cluster. Small organisms and organic detritus are brought to the mouth in water currents created by the cilia on the tentacles. The gut is bent upon itself, and the anus opens near the lophophore. Zooids may be modified for a variety of roles. Some do not possess a lophophore and act as regions for colony attachment, some act as stems to support the colony, and some act as brood chambers for the young. Other zooids are protective, and some are modifed for removing detritus and fouling organisms from the colony. These have a seizing apparatus resembling the beaked head of a bird. All zooids of a colony are interconnected and arise by asexual reproduction, budding from a free-swimming larva which develops from a fertilized egg. Some zooids in a colony may be male and some female.

On the Great Barrier Reef, calcareous encrusting bryozoans, often coloured pink, orange, red, or mauve, are abundantly represented around the bases and undersurfaces of corals, in the interstices of semi-consolidated rubble, on dead mollusc shells, under overhangs, on the walls of crannies and caverns, and on the undersurfaces of coral boulders. They are among the first macro-organisms to colonize freshly exposed surfaces on coral reefs. Obviously they play a major role in cementing together reef materials as well as contributing significantly to reef sediments. Other bryozoans form erect colonies in shaded areas, particularly on ledges and open spaces in back-reef areas. A few species grow in exposed situations. Erect and branching colonies often act as sediment traps, providing habitats for worms, crustaceans, and juvenile molluscs. Also, they provide food for a multitude of animals, particularly polychaete and nemertean worms (see chapter 9).

At least two hundred species, representing dozens of families, have been found on the Great Barrier Reef, and many more species remain



to be collected and identified. It would be premature to attempt to list the families of Bryozoa occurring there.

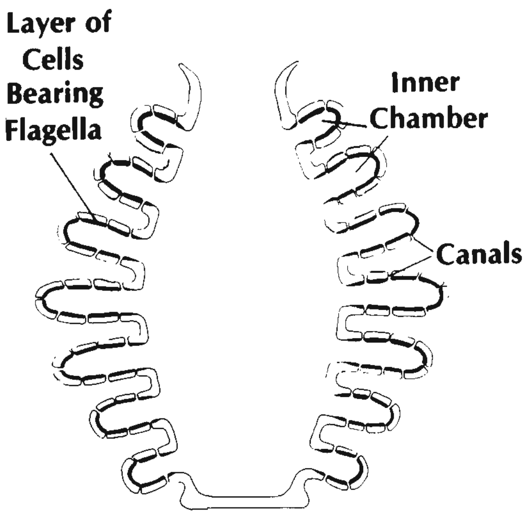
Some common genera represented: *Reteporella, Bugula, Watersipora, Celleparia, Fenestrulina, Rhynchozoon, Hippaliosina, Margaretta, Crepidacantha, Colletosia.*

Brachiopods (Phylum Brachiopoda)

Like bivalved molluscs, the soft parts of brachiopods are enclosed within a shell comprised of two calcified valves hinged together at one end. However, brachiopods are always attached to the substratum either by a stalk or by the cementing of one valve to the substratum. Internally, each valve is lined by a thin fleshy extension of the body called a *mantle*. In the mantle cavity is found a characteristic ringed or lobed lophophore, bearing ciliated filaments, which is a food-gathering and respiratory structure. A mouth is present near the lophophore and opens into a gut which lacks an anus. Sexes are usually separate, and there is a free-swimming larval stage. Brachiopods appear to be rather rare on the Great Barrier Reef. A few species (e.g. *Frenulina sanguinolenta*) have been found in the interstices of semi-consolidated rubble and live coral clumps on the reef flats of platform reefs. Species of the ducksbill brachiopod *Lingula* are found in soft sediments on some fringing reefs.

Genera represented: *Lingula, Frenulina.*

Sponges (Phylum Porifera)



Although sponges are commonly encountered on the Great Barrier Reef, the species found there have been little studied. Those present consist basically of sheets of cells that cover the outer and inner surfaces of the sponge and which line the numerous canals and chambers that characterize sponge structure. Each of the cells lining the inner chamber or chambers (see fig. 6) bears a long, whip-like flagellum as well as a circlet of minute tentacles surrounding the base of the flagellum. The beating of flagella cause currents of water to be drawn into the inner chamber or chambers by way of the canals that open on the outer surface. Food particles present in the water currents are extracted by the minute tentacles. Between the outer and inner sheets of cells mentioned is a region where some free, mobile cells occur as well as skeletal material. In some sponges the skeleton is of calcium carbonate occurring as individual spicules or as a fused mass of spicules. In other sponges the skeleton is composed of spicules of silica associated with organic fibres termed *spongin*. In still others, silicious spicules and spongin fibres overlay a massive calcareous skeleton. Sponges are all attached to the substratum and show a great variety of external form. Some are vase-shaped, some form fingerlike growths, some are straplike, some form spheres, some form coral-like growths, and many form encrusting sheets. Most sponges are hermaphrodites, both male and female sex cells being produced. Fertilization results in the formation of a free-swimming larva that eventually settles and develops into a sponge. Sponges also reproduce asexually by budding off clusters of cells, called *gemmules*, which develop into new sponges after release from their parent and attachment to the substratum.

In Great Barrier Reef waters sponges occur in a bewildering array of colours on the undersurfaces of coral boulders, in crevices and caverns, and on vertical faces in deeper water on the periphery of reefs. They occur also round the bases of living corals in association with algae and in some cases in exposed situations on top of reef rubble and semi-consolidated debris. Numerous species are obviously present, but they are so poorly known that it would be futile to attempt to list the families represented. Some species produce powerful antibiotics.

Some genera represented: *Leucosolenia, Tethya, Ircinia, Myxilla, Phyllospongia, Neofibularia, Pericharax, Jaspis, Phakellia.*

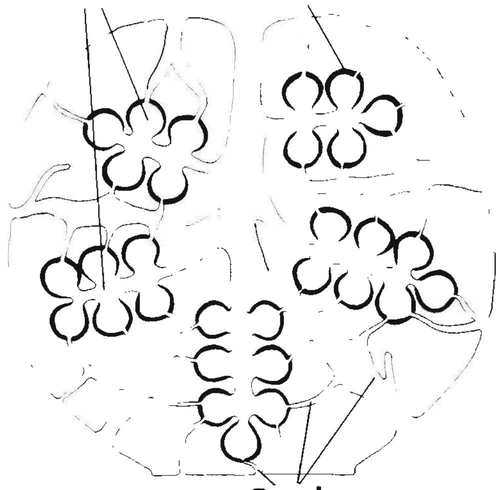


Figure 6. Vertical sections through generalized sponges. *Facing page, above:* A representative of species possessing a simple inner chamber. *Facing page, below:* A representative of species showing folding of the body wall. *Above:* A representative of species possessing a complicated system of canals and inner chambers.

Ascidians (Phylum Chordata, Class Ascidiacea)

Adult ascidians are vase-shaped animals attached at one end to the substratum. They occur as solitary individuals or as colonies. Each individual is enveloped by a tough *tunic* composed of fibres of a cellulose-like material called tunicin cemented together by other substances. Two openings in the tunic, called siphons, are associated with each individual. Water is drawn into one opening (the inhalent or *branchial siphon*) and passes to the anterior end of the gut (the pharynx) which has perforations called gill slits in its wall. Water passes through these slits into a cavity called the *exhalent chamber*, which opens to the exterior by way of the second siphon (the exhalent or *atrial siphon*). The water current itself is created by the beating of cilia on the gill slits. Food particles in the water current are ensnared in mucus secreted within the pharynx and pass to the stomach. From the stomach an intestine leads to the exhalent chamber.

Most ascidians are hermaphrodite, and the gonads also open into the exhalent chamber. Fertilized eggs usually give rise to a tadpole-like young, each of which settles on a surface after a short free-swimming existence and metamorphoses into a miniature adult. Asexual reproduction by budding is common in colonial species. The individuals of an ascidian colony, like those of a bryozoan colony, are known as zooids. Ascidians are well represented on the Great Barrier Reef, over two hundred species having already been found there. Most occur on rubble, particularly on the undersurfaces of dead coral boulders near reef crests. Many attach themselves to algae on reef flats, and some are found in dead mollusc shells. Numerous species occur in crevices, under ledges, in caves, and on vertical faces in deeper water on the edge of reefs. No doubt the list of ascidian species found on the reefs will be augmented considerably when these species are examined in detail. Ascidians show an amazing colour range, some species being spectacularly colourful. Families of ascidians found on the Great Barrier Reef are listed below:

Clavelinids (Clavelinidae) are colonial ascidians with relatively large zooids that often are semi-transparent. Frequently they protrude for much of their length from a common tunic, but in some species they are completely embedded in the tunic. Each zooid is divided into a thorax and abdomen. The branchial sac contains three to many rows of gill slits and is devoid of folds or longitudinal vessels. The gonad is confined to a loop of the gut in the abdomen. Atrial siphons are usually independent, but they may open into a common cloacal aperture in some species. Clavelinids occur under coral boulders, under overhangs, and in caves on reefs.

Genera represented: *Podoclavella, Eudistoma, Sigillina, Clavelina, Sycozoa, Pycnoclavella.*

Polyclinids (Polyclinidae) form massive colonies with the zooids completely embedded in the gelatinous or "cartilaginous" tunic and grouped in various ways. Each zooid is elongated and divisible into a thorax, abdomen, and post-abdomen, the latter division containing gonads and heart. The branchial sac is small but contains more than seven rows of gill slits. Usually the atrial apertures form a common cloaca, but in some species they are free. The branchial siphons have six to eight lobes. Polyclinids are found under coral boulders on reef flats and exposed in the deeper water on the edges of reefs.

Genera represented: *Polyclinum, Amaroucium.*

Didemnids (Didemnidae) are colonial ascidians usually forming flat encrusting sheets. Occasionally the colonies are globular. Frequently the common cloacal aperture shared by individual zooids of a colony is conspicuous, but the inhalent or branchial siphon of each zooid is more difficult to see because the zooids are minute. The branchial siphon has six lobes. Each zooid is divided into an anterior thorax containing the pharyngeal sac and a posterior region containing the gut and other organs. Tiny spicules, usually star-shaped, occur in the tunic. Didemnids, which are often brightly coloured, occur commonly under coral boulders on reef flats in Great Barrier Reef waters. They are also found exposed on reef flats either on coral rubble or associated with other organisms.

Genera represented: *Didemnum, Tridídemnum, Lissoclinum, Diplosoma, Leptoclinides.*

Diazonids (Diazonidae). Most diazonids are solitary, although colonial species in which the zooids are embedded in a common tunic do occur. These colonial zooids do not share a common cloacal aperture. The elongated body of each zooid is divided into an anterior thorax, containing a branchial sac which possesses many rows of gill slits, and a posterior abdomen. The U-shaped gut is in line with the principal axis of the zooid, and the gonad is contained in the loop. Diazonids appear to be rare in Great Barrier Reef waters. However, at least one species of this family occurs under boulders on reef flats.

Genus represented: *Rhopalea.*

Perophorids (Perophoridae) are colonial ascidians with the zooids connected only by ramifying stolons. The branchial sac has numerous gill slits and usually possesses inner longitudinal vessels. The loop of the gut lies to one side of the branchial sac. One species belonging to this family has been observed under coral boulders on some reefs.

Genus represented: *Ecteinascidia.*

Ascidiids (Ascidiidae) are solitary, attached forms. The branchial siphon is usually eight-lobed and the atrial siphon six-lobed. Straight gill slits are present in the branchial sac, which possesses inner longitudinal vessels. The loop of the gut containing the gonad is to one side of the branchial sac. Members of this family are relatively large ascidians. They occur on the undersurfaces of coral boulders and under overhangs on reefs.

Genera represented: *Ascidia, Phallusia.*

Styelids (Styelidae). Members of the large family Styelidae may be solitary or colonial. The body is not divided into thorax and abdomen. The siphons have smooth edges or are four-lobed. The branchial sac has fewer than five folds on each side. Gonads are present on the body wall on both sides of the animal. Some of the colonial styelids, in particular, are brightly coloured. Styelids grow on and under coral

boulders, under overhangs and ledges, and in caves on coral reefs.
Genera represented: *Botrylloides, Botryllus, Distomus, Polycarpa, Styela, Polyzoa, Cnemidocarpa, Chorizocarpa.*

Pyurids (Pyuridae) are solitary ascidians that frequently attain a large size. Usually the tunic, which is attached to the substratum, is leathery and tough and sometimes bears spines or tubercles. Both siphons have four lobes. In most species five or six folds are found in the branchial sac, which has small straight or spirally arranged gill slits. An obvious stomach associated with a lobed "liver" is present. One or more gonads are present on each side of the body. Pyurids are found attached to the undersurfaces of coral boulders and overhangs and in caves on reefs.
Genera represented: *Pyura, Herdmania, Microcosmus.*

Molgulids (Molgulidae) are solitary, usually spheroidal ascidians that are only occasionally attached to solid objects. Most live partially buried in the substratum. Frequently the tunic, which is usually translucent, carries fine processes to which sediment adheres. These processes act as anchors. Both siphons have six lobes. The gill slits in the pharynx are usually curved. Molgulids are not well represented on reefs of the Great Barrier Reef but are found commonly in soft sediments abutting on fringing reefs.
Genus represented: *Molgula.*

9

The Worms

Numerous worm-like groups of animals are found on reefs of the Great Barrier Reef. These groups are representative of some of the major subdivisions of the animal kingdom recognized by zoologists, and they differ markedly in bodily structure and function from group to group. However, they all have important roles to play in the coral reef community. Many are scavengers, breaking down organic detritus and recycling organic compounds. Others are active predators, feeding on small organisms. In turn they become prey for other animals. Generally, the worm-like animal groups found on the Great Barrier Reef have been somewhat neglected by zoologists.

Flatworms (Phylum Platyhelminthes)

Worms of the phylum Platyhelminthes are flat and usually thin. They have a distinct head that bears sense organs and a ramifying multibranched alimentary canal that has one opening serving as both mouth and anus. No respiratory structures, blood circulation, or body cavity are present. Most flatworms are hermaphrodites and have complex reproductive systems. Many are parasitic, the flukes and the tapeworms invariably so. These parasitic forms, found commonly in fish, turtles, marine snakes, birds, crustaceans, molluscs, and other animals often have several larval stages in their life histories, and the various larval stages may be found in different hosts. However, many flatworms are free-living, occurring under boulders and among rubble on reefs. Development in these forms may involve a larval stage or be direct.

Facing page
Illustration 92
A colony of the bluish clavelinid ascidian, *Podoclavella moluccensis.*

Illustration 93
A colony of the clavelinid ascidian, *Pycnoclavella detorta.*

Illustration 94
Part of a colony of a polyclinid ascidian (*Aplidium* sp.).

Illustration 95
Globular colonies of the didemnid ascidian, *Didemnum molle.*

Illustration 96
A solitary diazonid ascidian belonging to the genus *Rhopalea.*

Illustration 97
The two siphons of a partially hidden specimen of the solitary ascidiid ascidian, *Phallusia depressiuscula.*

Illustration 98
Colonies of a styelid ascidian belonging to the genus *Botryllus.*

Illustration 99
A group of pyurid ascidians, *Herdmania momus.*

Illustration 100
A colony of the orange polycitorid ascidian, *Polycitorella mariae.*

Illustration 101
A flatworm, *Pseudoceros bedfordi.*

Illustration 102
A flatworm, *Pseudoceros corallophilus.*

Illustration 103
A ribbon worm, *Baseodiscus* sp.

Free-living flatworms are usually oval in outline, flattened, and often semi-transparent. They range in size from a few millimetres to over 5 centimetres in length, but the majority are less than 1 centimetre. Some of the larger ones found on reefs are brightly coloured. They move over surfaces with a characteristic gliding motion and can swim by making undulatory movements of the body margins. Flatworms all appear to be carnivorous, prey being enveloped by a tubular and muscular proboscis that can be everted through the mouth. The flatworms occurring in Great Barrier Reef waters are not well known. Numerous families are probably represented there.

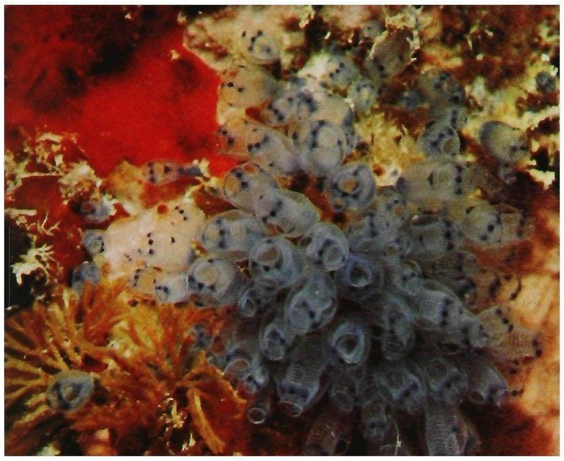
Some genera represented: *Pseudoceros, Thysanozoon.*

Roundworms (Phylum Nematoda)

Roundworms are well known as parasites of humans and domestic animals. However, many free-living species are found on the sea-floor. Most are microscopic, being less than 2 millimetres in length, but they are probably the most abundant of the animals associated with sea-floor sediments, including those of coral-reef areas. The translucent and unsegmented body of a roundworm is cylindrical or spindle-shaped and covered with a ,tough cuticle. Bristles arise from the body surface in some species. At the anterior end is a mouth surrounded by lips. Also situated at the front is a pair of sense organs called *amphids,* which occur in pits. The sexes are separate, and the fertilized egg gives rise to juvenile worms that develop into adults after a series of moults. Roundworms exhibit a characteristic writhing motion which enables them to move among sediments. Many species ingest organic debris and associated micro-organisms and serve to decompose and recycle organic nutrients. Other species are actively predacious. All, of course, are themselves preyed on by a multitude of animals.

Ribbon-worms (Phylum Nemertea)

Ribbon-worms are elongate, unsegmented worms with an amazing ability to contort their muscular bodies. In some species the body is flattened, in others it is cylindrical. The head is not sharply marked off from the rest of the body and, although bearing eyes, is frequently difficult to distinguish. A mobile, tubular proboscis bearing one or more stylets and, in some species, capable of injecting venom is used


92

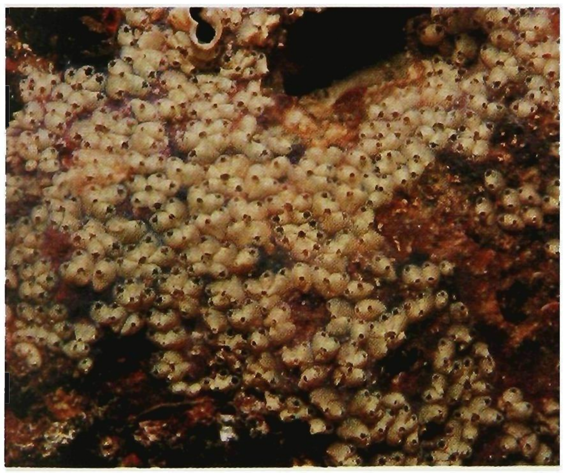

93


94


95


96


97


98


99


100


101


102


103

in the capture of prey. Sexes are usually separate, and in many species there is a free-swimming larval stage in the life history. Nemerteans are found among rubble and among algae on coral reefs. Some species are conspicuously marked and relatively large. *Baseodiscus quinquelineatus*, for example, carries five black lines on its body and may be over 50 centimetres in length. An orange species, *Gorgonorhynchus repens*, has a remarkable branched proboscis which writhes when shot out from the anterior end of the animal and looks like a mass of worms. Unfortunately, the ribbon-worms of the Great Barrier Reef area have received little attention from zoologists, and it is not known how many families are represented there.

Some genera represented: *Baseodiscus, Gorgonorhynchus.*

Peanut-Worms (Phylum Sipunculida)

The body of a peanut-worm is divided into a sac-like trunk (shaped like a peanut in some species) and a thinner tubular structure, the *introvert*, which is capable of great extension and which can be telescoped inside the trunk. The mouth is situated at the tip of the introvert, while the anus is placed towards the front of the trunk, the alimentary canal being bent upon itself. Sexes are separate. Development from the fertilized egg proceeds through a ciliated larval stage which is planktonic for a period. Peanut-worms are found under and among rubble, among algae, and burrowing in dead coral on reefs. The burrowers appear to extract organic material from material ingested whilst they are burrowing. Other peanut-worms collect detritus and minute organisms from surface films with the introvert which often carries ciliated tentacles.

Some genera represented: *Sipunculus, Siphonosoma, Aspidosiphon, Phascolosoma, Paraspidosiphon.*

Echiurid worms (Phylum Echiurida)

These are unsegmented finger-like worms that possess a broad extensible proboscis at the anterior end. The proboscis carries a ciliated groove on one side. A mouth is found at the junction of the proboscis with the trunk. Echiurids are not able to withdraw the proboscis into the body. The alimentary canal is long and coiled and the anal opening is found at the posterior end of the trunk which often carries rows of bristles. The sexes are separate, but in some species the male is much smaller than the female and is carried on or in her body.

Echiurids are occasionally found under rubble and in crevices in dead coral on reefs. They utilize the proboscis to feed on organic detritus and minute organisms in surface films. Echiurids found on the Great Barrier Reef have received little attention from zoologists.

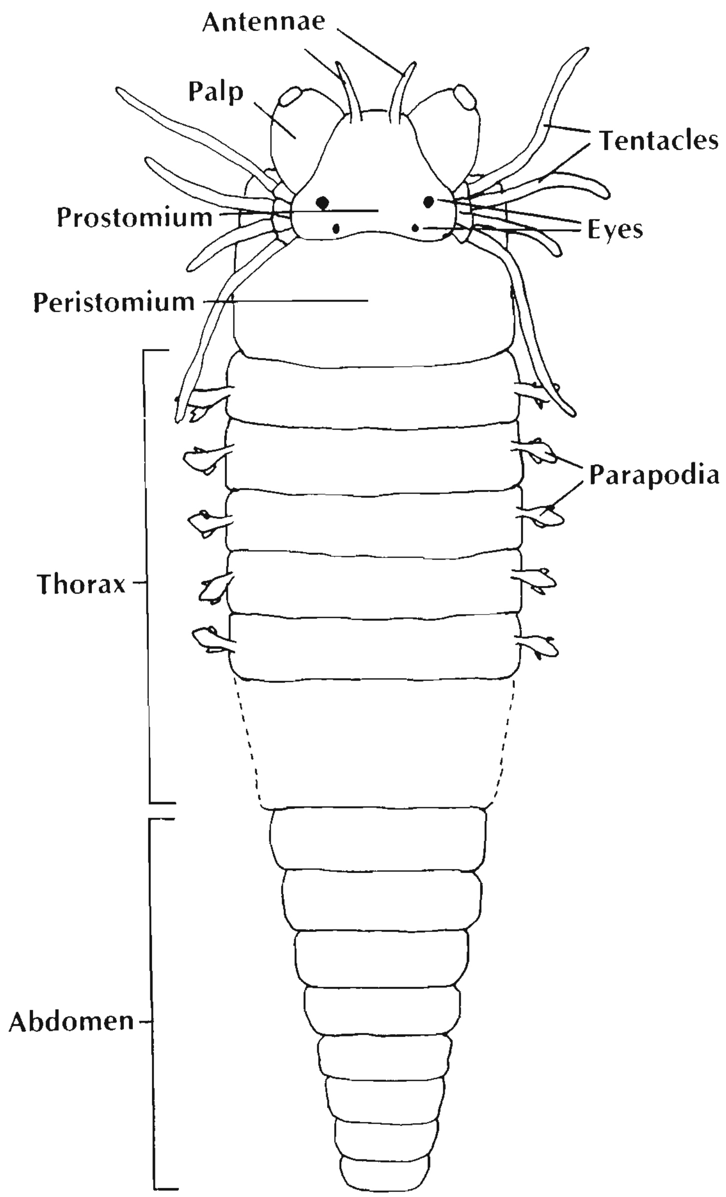
Polychaete Worms (Phylum Annelida, Class Polychaeta)

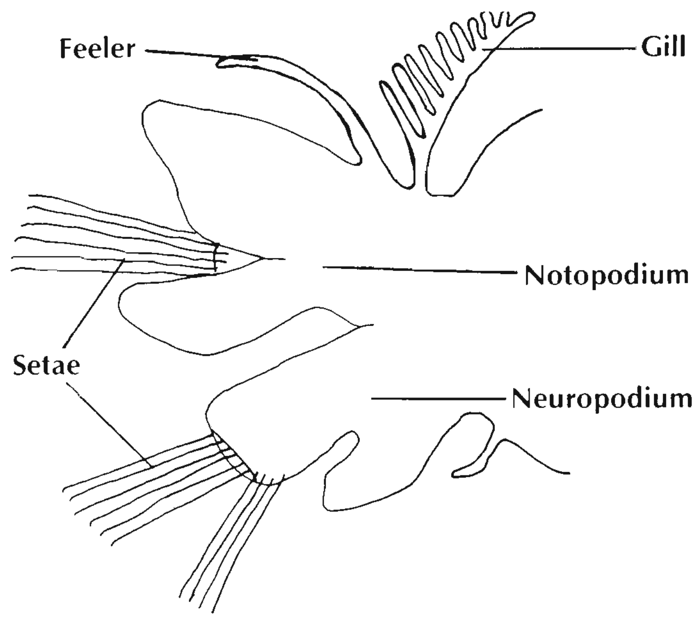
Polychaetes are elongated worms that are typically segmented and marine. Indeed, they are probably the commonest group of macroscopic organisms associated with marine sediments. Some species burrow in the sediments; others live in the interstices of semiconsolidated sediments or among rubble or on the surface of sediments. Some species live in association with sedentary organisms. Hence it is not surprising that polychaetes are abundantly represented on coral reefs.

Usually the head of a polychaete consists of two regions, the *prostomium* and *peristomium* (see fig. 7). The prostomium is the more anterior region and often bears eyes and appendages that take the form of expanded flaps called *palps* which may be sensory or involved in feeding or both, and pointed structures called antennae which are always sensory. The peristomium is found in the vicinity of the mouth and often carries tentacles that are sensory and may also assist in food capture. Each of the segments of the body found behind the head region usually bears lateral appendages known as *parapodia.* Typically, each parapodium consists of an upper (notopodium) and a lower (neuropodium) branch, each branch bearing tough structures called *setae* (see fig. 8). These are often bristle-like but assume a variety of forms in different polychaete groups. Sometimes one or both branches of the parapodium possess feelers or gills or both. Frequently the anterior end of the digestive system (the pharynx) can be everted through the mouth to form a tubular structure that is often armed with jaws for seizing prey (see fig. 9). In some groups, the region of the body behind the head is obviously divided into an anterior thorax and a posterior abdomen. Normally the sexes are separate in polychaetes, and most species liberate eggs and sperm directly into the water. Developmental stages may occur in the plankton or on the sea-floor. A few species brood their young.

Some polychaetes construct tubes which are often membranous but in some groups are calcareous. The bodies of tube-dwelling polychaetes are often modified, parapodia being frequently reduced and gills and food-collecting tentacles being often enlarged.

Representatives of numerous polychaete families have been recorded from the Great Barrier Reef. These families, together with a





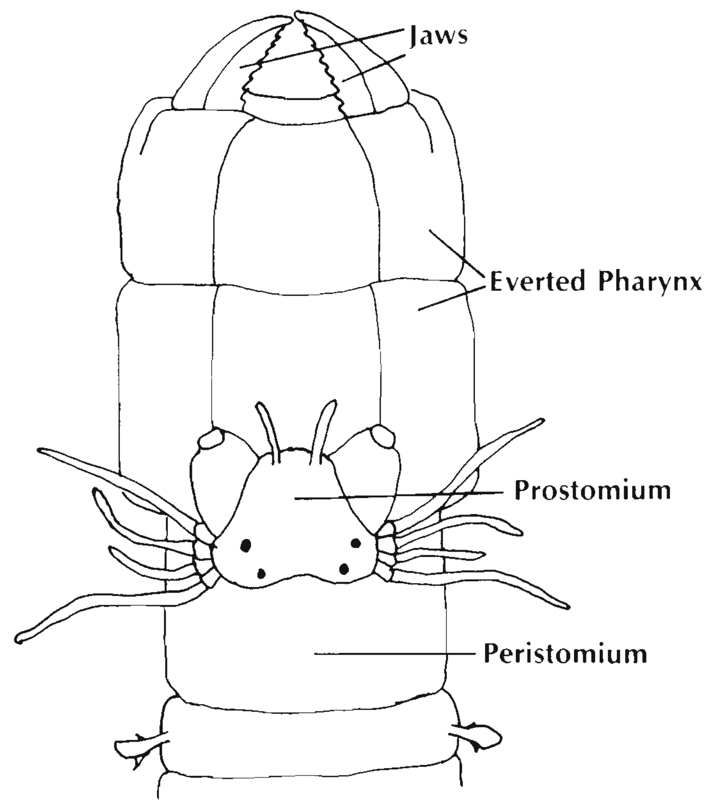


Figure 7. Top left: A generalized polychaete showing principal regions of the body and appendages.

Figure 8. Top right: A generalized parapodium of a polychaete.

Figure 9. Below: The anterior end of a polychaete showing everted pharynx with jaws.

brief description of the diagnostic features of each family, are listed below. However, the polychaetes of the Great Barrier Reef area are not well known. Representatives of additional families will undoubtedly be found there. At present it is not possible to list the genera represented.

Spionids (Spionidae). In the family Spionidae the prostomium is devoid of appendages. A pair or two groups of feeding tentacles occur on the peristomium. No jaws are present. Parapodia are usually well developed. Some spionids burrow into coral rubble and into mollusc shells on coral reefs. Others build tubes in the sand.

Chaetopterids (Chaetopteridae). The prostomium of chaetopterids carries a pair of short palps; the peristomium, a pair of tentacles. The body is divided into two or three regions. Each parapodium on the anterior region has only one branch, but there are two branches in the parapodia on posterior regions. Chaetopterids live in parchment-like tubes. On some fringing reefs and reef flats of platform reefs occurring near the Queensland mainland, the tubes of *Chaetopterus variopedatus* are often found. These are open at both ends, which project above the substratum. Water is drawn through the tube as a result of the movements of enlarged parapodia found near the middle of the worm. The water passes through a mucous filter secreted at the anterior end of the worm, and particulate material is filtered out. At regular intervals the particle-laden mucous filter is eaten and a new one secreted.

Capitellids (Capitellidae). No appendages are carried on the prostomium. The first and sometimes the second trunk segments are devoid of setae. Usually the setae of thorax and abdomen are obviously different. The lower portion of each parapodium is in the form of a transverse pad. Capitellids are threadlike and usually coloured reddish anteriorly. They are common in the interstices of partially consolidated rubble, under stones, and burrowing in coral sand on reef flats.

Bamboo-worms (Maldanidae). As their common name implies, bamboo-worms have elongated segments resembling those of bamboo stalks. Otherwise they resemble capitellids structurally and occur in similar habitats on coral reefs.

Scalibregmids (Scalibregmidae). The prostomium in members of the family Scalibregmidae is T-shaped or bifid and lacks appendages. Parapodia with upper and lower branches are present. The body is usually inflated anteriorly and usually has a wrinkled skin. Branching gills are often carried on the anterior body segments. Scalibregmids are found in sand under coral rubble on reef flats.

Opheliids (Opheliidae). In the family Opheliidae the prostomium is entirely devoid of appendages. Parapodia are poorly developed and carry only simple tapering setae. The body is usually short and often somewhat grublike. An unarmed eversible proboscis is present. Gills occur in some segments in some species. Opheliids are burrowers and occur in coral sand, especially around the bases of embedded rubble and in the interstices of coral rubble on reef flats.

Cirratulids (Cirratulidae). The prostomium is devoid of appendages. Grooved tentacles directed anteriorly arise from the peristomium or from one to several segments behind the peristomium, which is fused with two or more thoracic segments. Threadlike gills, or *branchiae*, are present on some segments. Cirratulids occur buried in sand or rubble or in the interstices of semi-consolidated rubble on reefs.

Paddle-worms (Phyllodocidae). Four or five antennae and small eyes are present on the prostomium, while four to eight tentacles arise from the peristomium in members of this family. An eversible proboscis, devoid of jaws, is used for food capture. The body is long and slender. Several species, many brightly coloured, belonging to this family have been observed on sand and among rubble on fringing and platform reefs.

Hesionids (Hesionidae) are short, flattened worms which carry two or three antennae on the prostomium and four to sixteen tentacles on the peristomium. An eversible pharynx, possessing jaws in some species but not in others, is present. The upper part of each parapodium (the *notopodium*) is smaller than the lower part (the *neuropodium*) but bears a long feeler. Hesionids are common in the interstices of dead coral clumps and under rubble on reef flats.

Nereids (Nereidae). Only two (sometimes one) antennae are found in nereids which have elongated, many-segmented bodies. Palps are present on the prostomium and four to eight feelers are found on the peristomium. The eversible pharynx is armed with a pair of jaws. Complex branches and feelers are associated with the parapodia. Nereids are found commonly in the interstices of coral rubble, under coral boulders, and among algae on reefs.

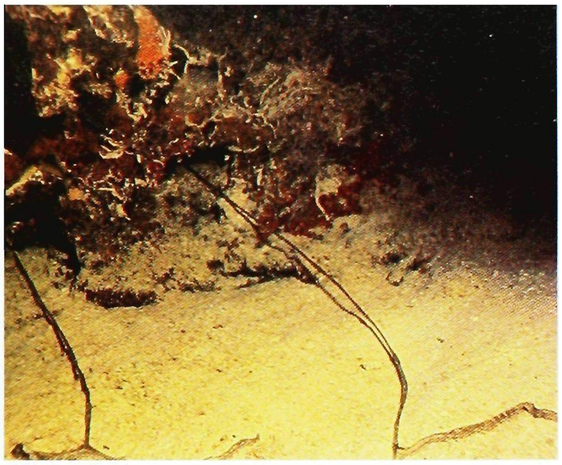
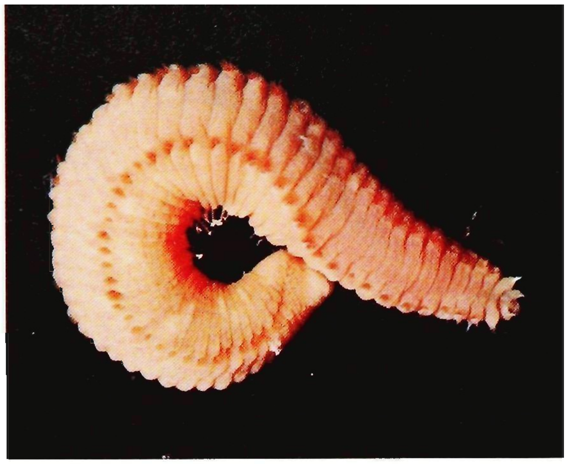
Glycerids (Glyceridae). Two pairs of antennae are borne on the markedly conical prostomium. The peristomium is devoid of feelers. The long pharynx, which is armed with four usually black jaws, is everted readily if glycerids are disturbed. Either the parapodia are all composed of upper and lower sections or they all have only one section. Glycerids are found among coral rubble. One species, *Glycera gigantea*, as the scientific name implies, is very large.

Syllids (Syllidae). Probably there are more species belonging to the family Syllidae on the Great Barrier Reef than belong to any other polychaete family. Syllids are small, usually threadlike worms that have three antennae and a pair of palps on the prostomium and four tentacles on the peristomium. An eversible pharynx, which is armed with teeth in some species but not in others, is present. Typically a prominent feeler is associated with the upper part of each parapodium. Syllids are abundant in the interstices of semi-consolidated coral rubble and in the bases of coral clumps on reef flats.

Fire-worms (Amphinomidae). One to five antennae, palps, and a backwardly directed sensory structure called a *caruncle* are present on the prostomium. Multi-lobed branchiae are associated with the upper portions of most parapodia. A roughened pad is present in the jawless pharynx. Spinose setae project in tufts from the parapodia. These setae are apt to penetrate and break off in the flesh of anyone handling the worms. There they cause intense irritation and often act as foci for infection. Large elongate specimens of the fire-worm *Eurythoe complanata* are found commonly under coral boulders on reef flats. Other long-bodied species of fire-worms occur among corals. Short-bodied, ovate fire-worms are also found on coral reefs, usually among and under rubble. Some fire-worms feed on corals.

Onuphids (Onuphidae). Seven antennae are found on the prostomium of onuphids. Jaws are present in the eversible pharynx. Sensory feelers are associated with the parapodia. Many onuphid species construct parchment-like tubes to which detritus often adheres. Others are burrowers. Most appear to be scavengers. Onuphids are found among coral rubble on reef flats.

Eunicids (Eunicidae). One to five antennae are carried on the prostomium. Several jaws are associated with the eversible proboscis. The upper portion of each parapodium is reduced to a sensory feeler and is associated with a many-lobed gill. Eunicids have been found in the interstices of semi-consolidated rubble and under coral boulders on reefs. Some species are large (over 1 metre in length in one case), and are active carnivores.


104

105

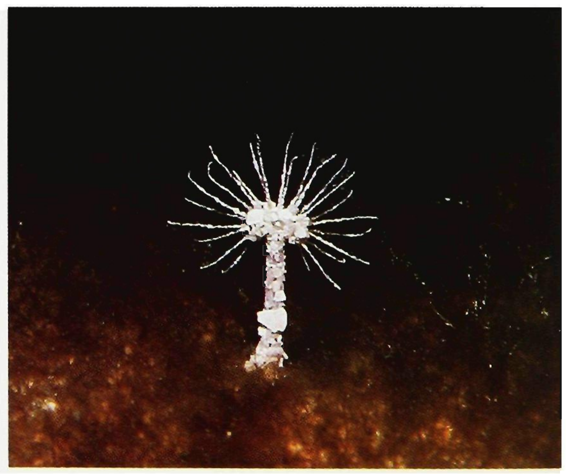
106

107

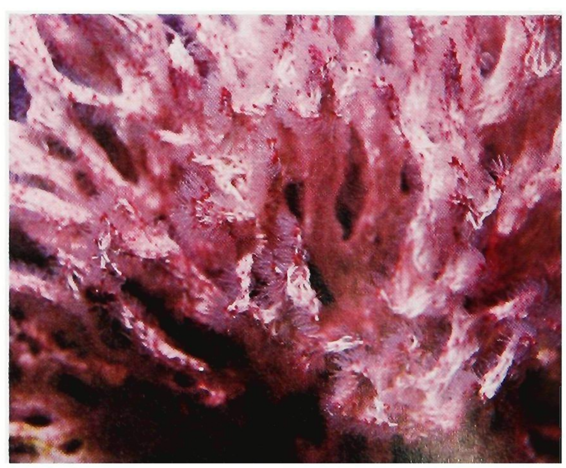
108

109

110

111

112

113

114

115

Lumbrinereids (Lumbrinereidae) carry no appendages on the prostomium. Several jaws are present in the eversible pharynx. The upper branch of each parapodium is absent or greatly reduced to form button-like structures. Lumbrinereids occur in the interstices of semi-consolidated rubble, in sand under coral boulders, and among the holdfasts of algae on reef flats.

Arabellids (Arabellidae) closely resemble lumbrinereids, differing mainly in details of their jaw apparatus. The two families occur in similar habitats on coral reefs.

Dorvilleids (Dorvilleidae). Two pairs of antennae are carried on the prostomium. Several jaws are present in the eversible proboscis. The upper portions of the parapodia are not as large as the lower portions, but both portions bear setae. Most members of the family are small. They have been found in the interstices of coral rubble.

Scale-worms (Polynoidae). A characteristic feature of the family Polynoidae is the presence of scales (elytrae) alternating with feelers on the upper surface of each segment. Three (sometimes one or two) antennae are usually present on the prostomium. Four jaws are found in the eversible proboscis. Scale-worms are usually flattened. Most are small to medium sized and are found on and under coral boulders. A few species live as commensals on other organisms, particularly echinoderms (see chapter 12).

Oweniids (Oweniidae). In members of the family Oweniidae the prostomium and peristomium are fused. The prostomium may be rounded or lobed or carry a crown of low tentacles. The anterior segments of the body are markedly longer than the posterior ones. Setae that take the form of small hooks occur densely in the lower part of each parapodium. Oweniids construct membranous tubes to which sand and shell fragments adhere. Usually only the anterior end of the tube projects from the sand and rubble in which the tube is buried or enmeshed. Species belonging to this family have been found in and among semi-consolidated rubble on reefs.

Flabelligerids (Flabelligeridae). In the family Flabelligeridae the prostomium carries lateral palps while the peristomium gives rise to filamentous branchiae. Both prostomium and peristomium can be retracted into the first three setae-bearing segments of the thorax. The body may be cylindrical or vasiform. Mucus that enmeshes sand grains and shell fragments is secreted by glands on the body surface. Consequently flabelligerids are often encased in sandy sheaths. They occur in and among rubble on coral reefs.

Facing page

Illustration 104
The bifid proboscides of two echiurid worms (*Bonellia viridis*) extending from a coral clump where the worms are hidden.

Illustration 105
A reef polychaete.

Illustration 106
The glycerid, *Glycera gigantea*, over one metre in length.

Illustration 107
The fire-worm, *Eurythoe complanata.*

Illustration 108
The setae of a fire-worm.

Illustration 109
A so-called sea-mouse, *Chloeia* sp.

Illustration 110
A scale-worm (Polynoidae) showing the overlapping scales (elytrae) on the upper surface.

Illustration 111
The spaghetti-worm, *Reteterebella queenslandiae.*

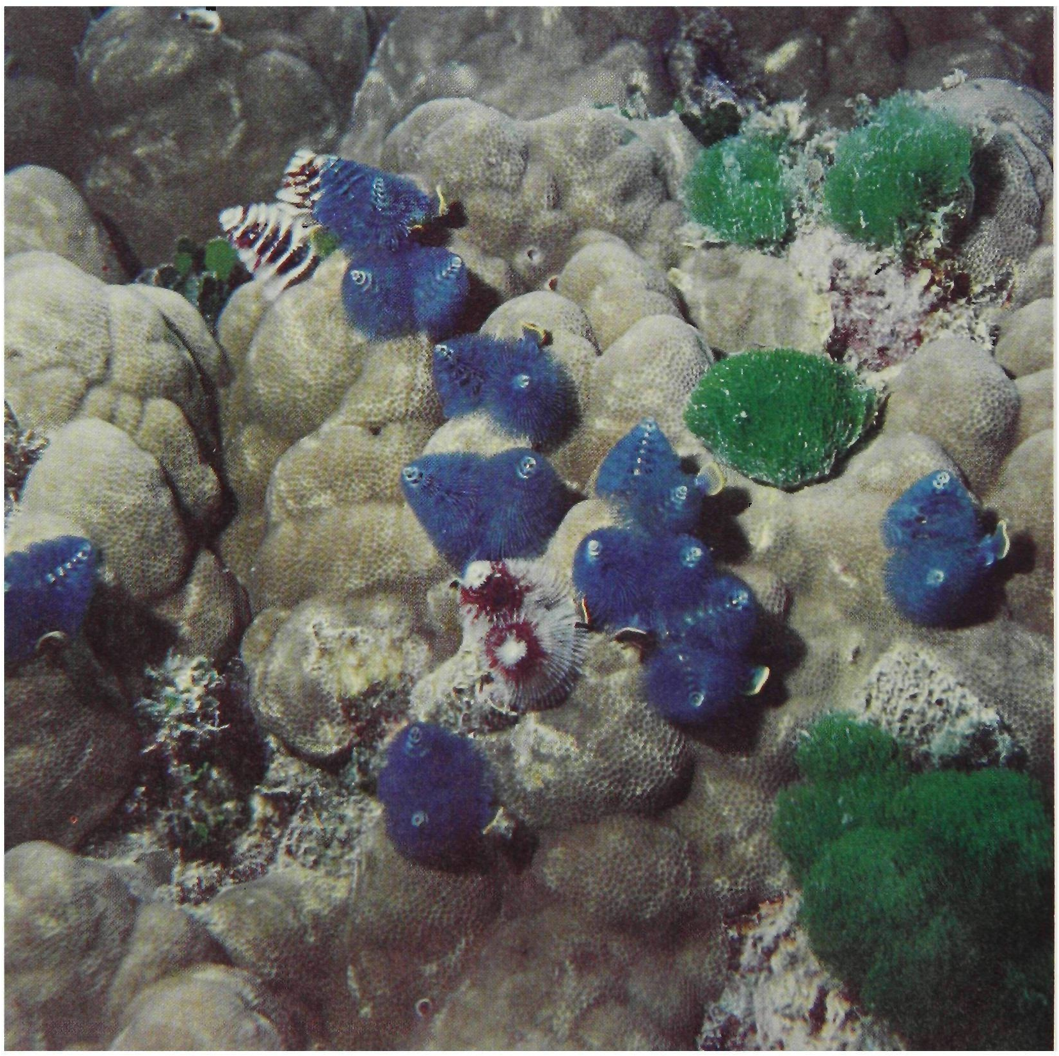
Illustration 112
An unidentified terebellid worm from Heron Island reef.

Illustration 113
The crown of tentacles belonging to a fan-worm of the genus *Sabellastarte.*

Illustration 114
The tentacles of a fan-worm, *Protula magnifica.*

Illustration 115
The calcareous tubes of specimens of the serpulid worm, *Filograna implexa.*

Terebellids (Terebellidae). The prostomium of terebellids has no appendages, but the peristomium bears numerous feeding tentacles that are usually long and highly contractile. Gills that are often markedly branched are found on the anterior segments. The parapodia of anterior segments of the body consist of upper and lower branches, but those of posterior segments consist of only one branch. Terebellids secrete mucous tubes to which sand, shells, and detritus adhere. On the Great Barrier Reef they are commonly found under coral rubble and around the bases of coral clumps. In some species (e.g., the so-called spaghetti-worm, *Reteterebella queenslandia*) the feeding tentacles often move actively over the surface of reef sediments, gathering organic detritus and minute organisms. In other species the tentacles filter particles from the water.



The spiral tentacles of a group of serpulid worms, *Spirobranchus giganteus*, protrude from their tubes which are embedded in coral. Most of the tentacles are blue in this group seen at Bowden reef.

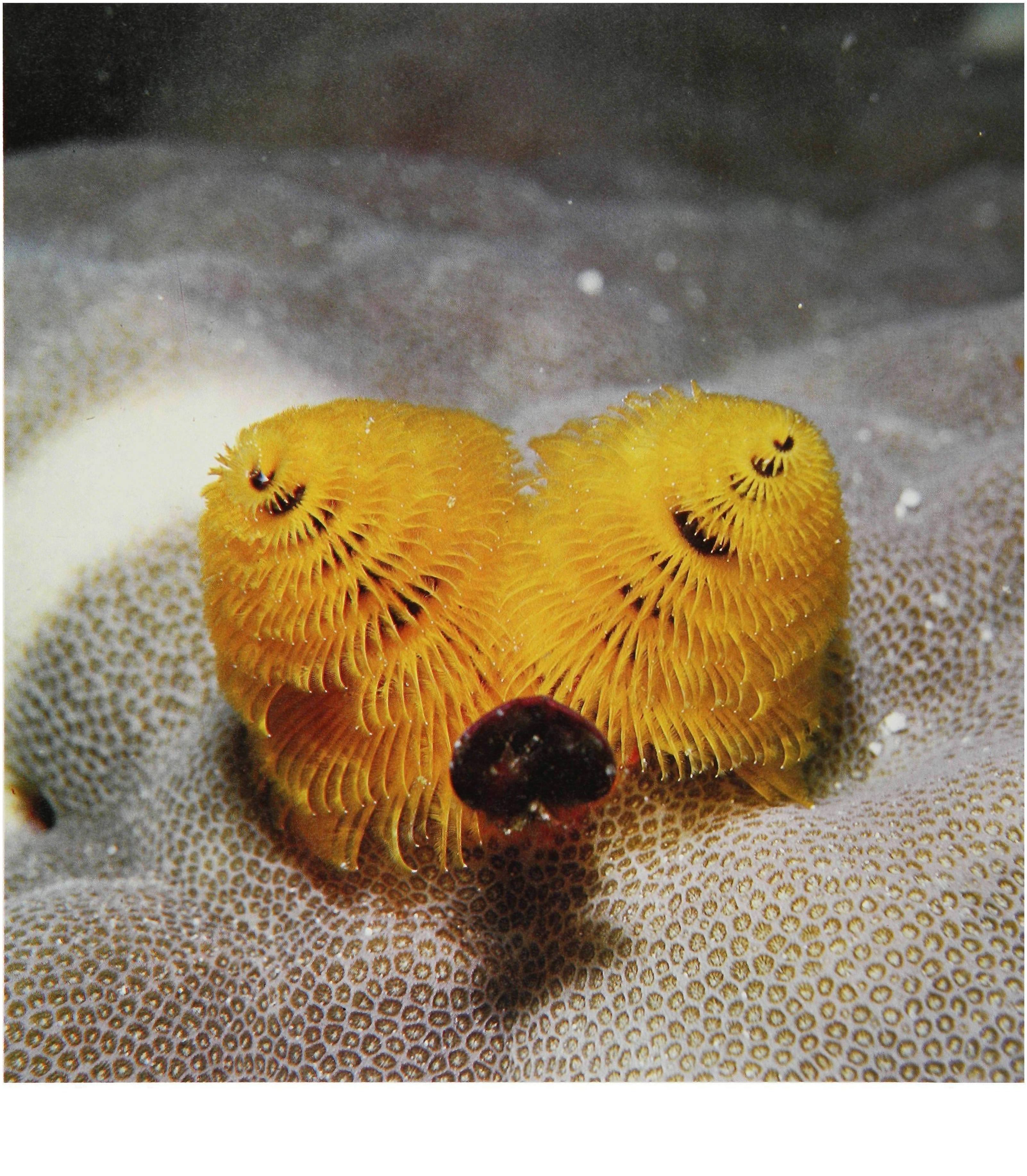
Fan-worms (Sabellidae). A fan of tentacles is present at the anterior end of the cylindrical body in sabellids, which secrete non-calcareous membranous tubes into which they withdraw for protection. The tentacles are used to collect planktonic organisms and detrital material and are also used in respiration. The prostomium is fused with the peristomium. Only a few of the thoracic segments carry setae. This is often the case with the abdominal segments, but in some species many abdominal segments carry setae. The tentacles of fan-worms are often reddish or banded with red. Some bear eyes. Some species of fan-worms attain lengths in excess of 15 centimetres and diameters exceeding 1 centimetre. On the Great Barrier Reef, fan-worms are found attached to coral boulders and partially embedded in semi-consolidated rubble on reef flats.

Uncoiled calcareous tube-worms (Serpulidae). In members of the family Serpulidae a crown of tentacles used to collect food as well as for respiratory purposes surrounds the anterior end of the body. A calcareous tube, which may be straight or twisted, is secreted, and the animal withdraws into this when alarmed. The body of the worm is symmetrical. These tube-worms are common on and under coral boulders and slabs of beach rock on reef flats. One species, the so-called peacock-worm, *Spirobranchus giganteus,* is commonly associated with live corals, particularly species of *Porites* (see chapter 17).

Coiled calcareous tube-worms (Spirorbidae) closely resemble members of the family Serpulidae. However, their bodies are asymmetrical and the calcareous tubes secreted are coiled into a spiral. These tube-worms are found under boulders on the reef flat.

Oligochaete Worms (Phylum Annelida, Class Clitellata, Subclass Oligochaeta)

Oligochaete worms resemble polychaetes, but they are devoid of parapodia, the few setae they possess arising directly from the body wall. The most anterior region of the body, the prostomium, lacks appendages. Gonads are confined to a few segments, and all species are hermaphrodite. An egg case is produced by the glandular skin of a few segments. It is only in recent years that oligochaetes have been reported from any reef of the Great Barrier Reef. However, they appear to be quite common at Heron and Wistari reefs in the Capricorn group, and no doubt oligochaetes will be found elsewhere on the Great Barrier Reef.



Tubificids (Tubificidae) are small oligochaete worms whose gonads are found in segments 10 and 11 and receptacles for the receipt of sperm in segment 10. Tubificids burrow in coral sand near coral clumps.
Some genera represented: *Aktedrilus, Bathydrilus, Coralliodrilus, Heronidrilus, Limnodriloides, Phallodrilus, Jamiesoniella.*

Enchytraeids (Enchytraeidae). The gonads of enchytraeids are found in segments 11 and 12 and receptacles for the receipt of sperm in segment 5. These small worms burrow in sand near coral clumps.
Genus represented: *Grania.*

Phoronids (Phylum Phoronida)

A characteristic feature of the small group of wormlike animals called phoronids is the presence of a biolobed fan of tentacles surrounding the mouth at the anterior end of each individual. The posterior end is swollen. The gut is bent upon itself, and the anus also opens anteriorly. Each phoronid is housed in a chitinous tube into which it withdraws its anterior end and tentacles when disturbed. Mucus secreted by the tentacles ensnares organic debris and micro-organisms that are brought to the mouth by water currents created by cilia on the tentacles. Phoronids occur in sandy areas around the bases of corals and coral rubble on reef flats. Possibly only one species occurs there.
Genus represented: *Phoronis.*

Acorn-Worms (Phylum Hemichordata, Class Enteropneusta)

The body of acorn-worms is divided into the proboscis, the collar, and the elongate trunk. The anterior proboscis is a sensory and food-collecting structure, detritus and minute organisms being enmeshed in mucus and passed back by currents created by cilia on the proboscis to the mouth situated on one side of the collar. Gill slits which carry cilia occur in the pharynx region of the alimentary canal. Beating of these cilia causes water to be drawn into the alimentary canal through the mouth and to pass through the gill slits to the exterior. The current thereby created is involved with respiration. Acorn-worms occur in sandy regions of coral reefs, particularly in lagoons and back-reef areas.
Genus represented: *Balanoglossus.*

Facing page
The yellow spiral tentacles of this specimen of *Spirobranchus giganteus* project above the coral in which its tube is embedded.